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CONSEIL PERMANENT INTERNATIONAL
POUR L'EXPLORATION DE LA MER
CHARLOTTENLUND SLOT – DANEMARK

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VOL. XIII · NO. 2

PUBLIÉ PAR LE BUREAU DU CONSEIL

RÉDIGÉ PAR

E. S. RUSSELL

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
COPENHAGUE

AOÛT 1938

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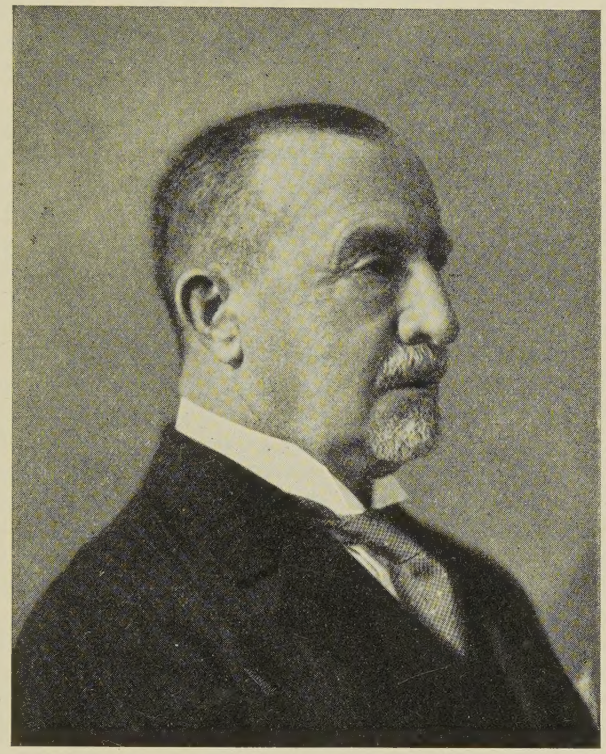
Errata.

M. G r a h a m: Rates of Fishing and Natural Mortality from the Data of Marking Experiments.

p. 86 $4 \times \frac{981}{1000}$ should read $4 \times \frac{186}{1000}$

p. 89 $100_e^{-(0\cdot74 + 0\cdot35)} = S_2$ should read $100\ e^{-(0\cdot74 + 0\cdot35)} = S_2$

IMPRIMERIE A/S L. IHRICH



Knud Schøning

1860—1938.

THE news of the death of Captain Schøning on July 18th undoubtedly came as a surprise to his many friends in spite of his age — seventy-eight. He was born on October the 5th, 1860, in Copenhagen, a son of Colonel Valdemar Schøning. At the age of 18 he entered the Naval College and was appointed Sub-Lieutenant in 1883 and in 1884 promoted to Lieutenant. After 14 years' service he

spent a four years' furlough as Captain of one of the East Asiatic Company's vessels. Promoted to Commander in 1901 and having served another year in the Danish Navy, his yearning for wider fields again drew him from Denmark and the nine years — 1903—1912 — were spent as a Captain in the Siamese Navy, partly as First Naval Aide-de-Camp to H. M. the King of Siam.

Captain Schøning was one of the Danish pioneers of the East, both in the service of the East Asiatic Company and in the Siamese Navy and thanks to his work for this Navy, then just being developed, Danish naval officers were always welcome in Siam; the good relationship between officers from the two navies, definitely cemented during the early part of this century, was due to some extent to Captain Schøning's work in the East.

On his return he was engaged by the Bureau as Statistician to the Council, and for 15 years, until the death of the General Secretary, Captain Drechsel, he filled this post to the full satisfaction of everybody interested in the Bulletin Statistique. For another five years this work was continued in connexion with his work as Administrative Secretary to the Council, a post instituted in substitution of the post of General Secretary. In 1932, at the age of seventy-two, Captain Schøning was pensioned and retired from the service of the Council.

On his retirement from the Danish Navy in 1906, he was decorated with the Cross of the Order of the Dannebrog, and in 1918, after 4 years' temporary service as commander of the naval depot "Lynetten", he received the Cross of Honour of the Order of the Dannebrog.

An eventful life was finished, pleasures and disappointments came to an end after but a few days illness, when on July the 18th Captain Schøning was allowed to depart peacefully from life. His many friends in Denmark and abroad will remember Captain Schøning's friendly and good-natured personality, always ready to give his assistance to anybody who asked.

W. N.

May I be allowed to write a few words about my old friend Captain Schøning, in addition to the biographical note of the present Administrative Secretary? Having been closely associated with him for many years, and especially

during the period of his service as Administrative Secretary, I think I am qualified to speak of Schøning, the man.

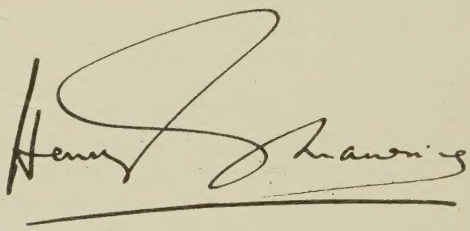
When the Bureau invited him to take charge of the office at Copenhagen, they asked him to undertake a difficult task. Captain Drechsel had died after a very short illness. The Bureau felt the need of a man to take charge of the office. The man on the spot was Captain Schøning, and their choice fell upon him. He had worked as Statistical Officer for years, and, therefore, was familiar with some aspects of the work of the Council and was known both to the Council and to the staff. Schøning, accordingly, was to follow Drechsel — in a less independent, but still in a responsible position. And Drechsel was a hard man to follow; a man of outstanding and masterful personality, one of the founders and pillars of the Council, highly regarded in every quarter, and thus exercising an authority which no-one could challenge and few, if any, would have had the courage to challenge.

Schøning, having accepted the task, became, or, rather, continued to be, the faithful servant of the Council. He cheerfully and loyally filled a gap. The most responsible duties of the General Secretary were taken over by the President; Schøning, as Administrative Secretary, took over, in addition to his statistical work, the routine duties of the office. Hampered, as he was, by deafness, he carried them out with loyal zeal, and, when the term for which he was appointed came to an end, he made way without grumbling for a younger man. I had every reason, from beginning to end, to be grateful to him and I wish to place my gratitude on record. With his zeal and loyalty Schøning combined much of the blunt outspokenness of the old sea-dog and a good deal of the old sea-dog's obstinacy. But his obstinacy was never carried beyond the point of insisting that what he thought and felt should be expressed, argued and duly considered. If he was overruled he accepted the situation according to the tradition in which he had been brought up — the tradition of naval discipline.

Nothing was more characteristic of his straightforward, independent spirit than what happened but a few years before his death. The Council had allotted him a pension which was to come to an end at the expiration of a term of years. His health was not good, and I think a good many of us felt that he was unlikely to outlive the period of his pension. As the period neared its end the subject of the renewal of his

pension was mooted. We all knew that he had invested his private means in rubber and that his investments had become not only unremunerative, but unsaleable. At the critical time the rubber market made a remarkable recovery. Taking advantage of this improvement, Schøning was able to realize a sum sufficient for his needs and promptly informed his successor that, if there was any question of renewing his pension, he wished it to be known that it was unnecessary and that he would not accept any further pension than that which had been voted to him.

Knowing him as I did, I feel that he found great happiness in the complete independence of his closing years. The thought gives me great happiness now that my old friend is dead. He was a very worthy representative of the fine spirit of his native country, which has weathered so many storms and, as we all hope and believe, will be able to weather whatever storm or tempest may threaten it hereafter.



Eddy Diffusion at Mid-Depths in the Caribbean Sea Region.

By

H. R. Seiwell.[1])

1. Vertical Diffusion in the Caribbean Basin.

THE extensive distribution and close vertical relationship of the principal salinity and oxygen minima in the Caribbean Sea region[2]) provides a convenient basis for estimation of the magnitude of eddy diffusion at mid-depths in that region. In the following procedure the approximate average value of the mean vertical eddy coefficient in a layer (approximately 100 metres thick) between the minimum oxygen and minimum salinity concentrations in the eastern part of the Caribbean basin (based on "Atlantis" stations 1492—1504, section I, and 1505—1515, section II) is calculated. It is assumed, for purposes of calculation, that only small vertical variations of horizontal velocity occur within the stratum concerned, and, also, as a first approximation, it was further assumed that the only eddy component producing a measurable diffusion effect was that acting along the vertical. Hence, changes in concentration of the minimum oxygen value (Fig. 1) between sections I and II are considered to result from the combined effects of biological activity and vertical eddy diffusion[3]), whereas changes in concentration of the salinity minimum (Fig. 2) are considered to be due solely to vertical diffusion.

[1]) Contribution No. 177 from the Woods Hole Oceanographic Institution.

[2]) A discussion of this situation is found in "Application of the Distribution of Oxygen to the Physical Oceanography of the Caribbean Sea Region," by H. R. Seiwell. To be published in *Papers in Physical Oceanography and Meteorology* as Contribution No. 162 from the Woods Hole Oceanographic Institution.

[3]) Between sections I and II the average concentration of the oxygen minimum decreased, showing an excess of consumption by biological activity over that gained by turbulence.

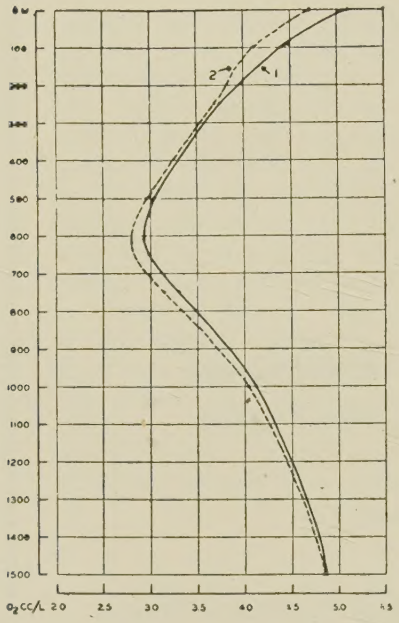


Fig. 1. Mean vertical distribution of oxygen (c.c. per litre) for section I (stations 1492—1504) and section II (stations 1505—1515) in the eastern part of the Caribbean basin.

The consumption of oxygen at the depth of its minimum concentration during the time (t) it takes this water to move horizontally from section I to II would be:

$$Ct = O_1 - O_2 + \frac{\Delta O}{\Delta t} t$$

where C is the rate of oxygen consumption per unit time, $O_1 - O_2 =$ the difference in the observed mean minimal oxygen concentrations of sections I and II, and $\frac{\Delta O}{\Delta t}$ is the amount of oxygen supplied per unit time due to vertical mixing (changes due to the lateral eddy components were neglected). We get from the general equation for vertical diffusion:

(1) $$\frac{\Delta O}{\Delta t} = \frac{A}{\varrho} \frac{\delta^2 O}{\delta Z^2}$$

and, thence, by substitution:

(2) $$O_1 - O_2 + t\left(\frac{A}{\varrho} \frac{\delta^2 O}{\delta Z^2} - C\right) = 0$$

This equation contains two unknowns, t and A, and was solved by a consideration of the minimum salinity concentrations at mid-depths of sections I and II (as represented by stations 1499 and 1510, Fig. 2). Thus, the application of Jacobsen's equation[4]) to the temperature-

[4]) Jacobsen, J. P. "Eine graphische Methode zur Bestimmung des Vermischungskoeffizienten im Meere." Gerl. Beitr. zur Geophysik, Vol. XVI, pp. 404—412.

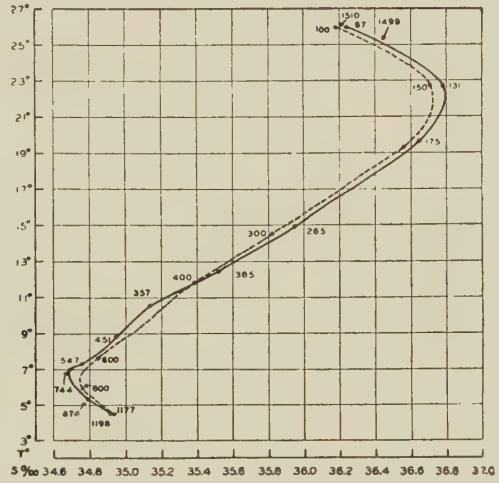


Fig. 2. Temperature-salinity relations for stations 1499 and 1510 in the eastern part of the Caribbean basin.

salinity relationship of the strata adjacent to the salinity minima of stations 1499 and 1510 (assuming a steady state as the water moves from section I to II) would give:[5])

$$t\frac{A}{\varrho} = \frac{S^2}{8} \tag{3}$$

It may be accepted that the relative functional relationships of temperature and salinity of sections I and II, in the vicinity of the salinity minimum, are represented with sufficient accuracy by those for stations 1499 and 1510 (which lay at approximately mid-points of their respective sections), and there is no need to use mean values for the entire sections as was done for the less accurate oxygen values. Equations (2) and (3) may be combined into a simultaneous system and solved for t and A (on the basis of previous assumptions these quantities both in equation (2), involving the minimum oxygen concentration, and equation (3), involving the minimum salinity concentration, are taken to be equivalent), thus:

$$t\left[\frac{A}{\varrho}\frac{\delta^2 O}{\delta Z^2} - C\right] = O_2 - O_1$$

$$t\frac{A}{\varrho} \qquad\qquad - \frac{S^2}{8}$$

which gives on solving:

$$t = \frac{O_1 - O_2}{C} + \frac{\delta^2 O}{\delta Z^2}\frac{S^2}{8C} \tag{4}$$

Equation (4) may be evaluated with the aid of data plotted in Figures 1 and 2. The difference in mean minimum concentration

[5]) The density of sea water ($\varrho = 1{\cdot}02$, approximately) is not utilized in the practical application of the diffusion equations.

$(O_1 - O_2)$ between sections I and II was 0·16 c.c per litre $= 1{\cdot}6 \times 10^{-4}$ cm.^{3} g.$^{-1}$ and the mean value of $\frac{\delta^2 O}{\delta Z^2}$ at 615 metres (mean depth of oxygen minimum concentration) for sections I and II, was:

$$\frac{\delta^2 O}{\delta Z^2} = 2.40 \times 10^{-12} \text{ cm.}^3 \text{ g.}^{-1} \text{ cm.}^{-2}$$

The value, $S = 2{\cdot}25 \times 10^4$ centimetres, was determined graphically from the combined temperature-salinity relationships of stations 1499 and 1510 (Fig. 2). The value of oxygen consumption per unit time, C, was taken to be $1{\cdot}35 \times 10^{-11}$ cm.^{3} g.$^{-1}$sec.$^{-1}$ (0·42 cc. per litre per year), the mean value of oxygen consumption previously calculated for the oxygen-poor layer at mid-depths of the tropical mid-Atlantic[6]).

Substitution of these values in equation (4) would give:

$$t = 2{\cdot}3 \times 10^7 \text{ sec.} = 0{\cdot}7 \text{ year}$$

and the mean vertical eddy diffusion coefficient characterizing the water column at mid-depths, between the salinity and oxygen minimum in the eastern Caribbean, would then be:

$$A = 2{\cdot}8 \text{ C.G.S. units.}$$

The distance, X, between stations 1499 and 1510 (both of which are located near the mid-points of their respective sections) is approximately the same as the mean distance between sections I and II, or $X = 4{\cdot}45 \times 10^7$ centimetres. Thus, the mean horizontal velocity in the layer bounded by minimum salinity and minimum oxygen concentrations was calculated to be:

$$\mu = \frac{\Delta x}{\Delta t} = 2{\cdot}0 \text{ cm.sec.}^{-1}.$$

Due to the various assumptions involved (the effect of horizontal eddy diffusion was entirely neglected), the values for A and μ are considered to be only approximate, but they are probably of the correct order of magnitude; the value of $A = 2{\cdot}8$ C.G.S. units is within the limits established by other investigations for the vertical eddy diffusion coefficient at mid-depths.

The plausibility of the calculated values for A and μ may be tested in a manner similar to that used by Defant[7]) for estimating the relation of the eddy coefficient to the horizontal velocity in the deeper parts of the South Atlantic. On assumption of steady motion, the existence of the relation involving only the vertical eddy component,

[6]) See Seiwell, H. R.: "The distribution of oxygen in the western basin of the North Atlantic." Papers in Phys. Ocean. and Meteorol., Vol. III, No. 1. 86 pp. 1934.

[7]) Defant, Albert. "Zur Dynamik des Antarktischen Bodenstromes im Atlantischen Ozean." Zeitschr. für Geophysik, Vol. XI, pp. 50—55.

$$\frac{A}{\mu} = \varrho \frac{\frac{\delta\alpha}{\delta x}}{\frac{\delta^2\alpha}{\delta Z^2}} \tag{5}$$

allows calculation of the ratio, $\frac{A}{\mu}$, where $\frac{\delta\alpha}{\delta x}$ denotes horizontal variation of the conservative property, α, in the direction of flow and $\frac{\delta^2\alpha}{\delta Z^2}$ the curvature of its vertical variation; the co-ordinate system being oriented so that the X-axis points in the direction of flow, velocities in all other directions are assumed to be zero. Thus, application of equation (5) to salinity data from the vicinity of the salinity minima of stations 1499 and 1510 (Fig. 2) gives:

$$\frac{A}{\mu} = \frac{1{\cdot}35 \times 10^{-12}}{10^{-12}} = 1{\cdot}35.$$

as the ratio existing in the vicinity of the salinity minimum; this result is in good agreement with the ratio, $\frac{A}{\mu} = \frac{2{\cdot}8}{2{\cdot}0} - 1{\cdot}4$, from results of the previous calculation in the vicinity of the oxygen minimum.

Further application of the fundamental differential equation regulating diffusion of substances in the sea by vertical turbulence alone (equation 1) to the temperature and salinity data in the vicinity of the oxygen minimum at stations 1499 and 1510 supports the value, $A = 2{\cdot}8$ C.G.S. units, as approximately correct for the existing circumstances. Thus, denoting observed temperature ($t°$) and salinity (S) values (at the depth of the oxygen minimum) for station 1499 (section I) by the subscript 1 and for station 1510 (section II) by the subscript 2, we have:

$$S_2 - S_1 = 9 \times 10^{-5} \text{ g. g.}^{-1}$$
$$t_2° - t_1° = 3{\cdot}5 \times 10^{-1} \text{ deg.}$$

showing that increases both in salinity and temperature have taken place by mixing processes as the water at mid-depths (at depth of the principal oxygen minimum) near the central axis of the Caribbean basin, moves westward from station 1499 (section I) to station 1510 (section II). The average oxygen content at the depth of its minimum concentration actually decreased between sections I and II, showing an excess of oxygen consumption (by biological processes) over that gained by mixing; the mean difference in oxygen content between sections I and II was calculated to be:

$$O_2 - O_1 = -1{\cdot}6 \times 10^{-4} \text{ cm.}^3 \text{ g.}^{-1}$$

Mean values for the second derivatives of the vertical salinity, temperature, and oxygen gradients for stations 1499 and 1510 at the depth of the oxygen minimum concentration were:

$$\frac{\delta^2 S}{\delta Z^2} = 10{\cdot}0 \times 10^{-13}\ \text{g}\cdot\text{g.}^{-1}\ \text{cm.}^{-2}$$

$$\frac{\delta^2 t^\circ}{\delta Z^2} = 5{\cdot}7 \times 10^{-9}\ \text{deg. cm.}^{-2}$$

$$\frac{\delta^2 O}{\delta Z^2} = 2{\cdot}4 \times 10^{-12}\ \text{cm.}^3\ \text{g.}^{-1}\ \text{cm.}^{-2}$$

And the time rates of changes as computed from the equation

$$\frac{d\alpha}{dt} = \frac{A}{\varrho}\frac{\delta^2 \alpha}{\delta Z^2} \tag{6}$$

when A = 2·8 C.G.S. units, are:

$$\frac{ds}{dt} = 2{\cdot}80 \times 10^{-12}\ \text{g. g.}^{-1}\ \text{sec.}^{-1}$$

$$\frac{dt^\circ}{dt} = 1{\cdot}60 \times 10^{-8}\ \text{deg. sec.}^{-1}$$

$$\frac{dO}{dt} = 6{\cdot}74 \times 10^{-12}\ \text{cm.}^3\ \text{g.}^{-1}\ \text{sec.}^{-1}$$

Integrating between the limits, $t = 0$ and $t = 2{\cdot}3 \times 10^7$ seconds (the time calculated for the water to move from station 1499 to 1510, page 158), gives the amount of change in temperature, salinity, and oxygen resulting from vertical diffusion as the water at the depth of the oxygen minimum moves from station 1499 to 1510 (the results are entered in Table 1).

Table 1.

Property	Observed change	Calculated change	Computed — Observed
Oxygen	$-1{\cdot}6 \times 10^{-4}$	$1{\cdot}5 \times 10^{-4}$	$3{\cdot}1 \times 10^{-4}$ cm.^{3} g.$^{-1}$
Temperature ..	$3{\cdot}5 \times 10^{-1}$	$3{\cdot}7 \times 10^{-1}$	2×10^{-1} deg.
Salinity	$9{\cdot}0 \times 10^{-5}$	$6{\cdot}4 \times 10^{-5}$	$-2{\cdot}6 \times 10^{-5}$ g. g.$^{-1}$

Comparison of observed and calculated change in concentration of identifying properties at depth of minimum oxygen concentration between stations 1499 and 1510 in Caribbean basin. Difference between computed and observed oxygen values represents the approximate amount of oxygen consumed by biological processes between section I and II. Thus: $\frac{3{\cdot}1 \times 10^{-4}\ \text{cm.}^3\ \text{g.}^{-1}}{2{\cdot}3 \times 10^7\ \text{sec.}} = 1{\cdot}35 \times 10^{-11}\ \text{cm.}^3\ \text{g.}^{-1}\ \text{sec.}^{-1}$

The agreement between observed and calculated change in the two conservative properties (temperature and salinity) is sufficiently good to substantiate the approximate correctness of the value 2·8 C.G.S. units for the vertical eddy transfer coefficient.

2. Lateral Diffusion in the Caribbean Basin.

In the above discussion of eddy diffusion, only the effects produced by vertical components of turbulent motion have been considered; any effect from lateral turbulence has been neglected in order to simplify the treatment. Likewise, more information is available on the lateral

diffusion accompanying fluid motion of the atmosphere than of the ocean, and, in the former, the order of magnitude of horizontal diffusivity coefficients has been calculated to be (according to investigations of Defant[8]), and Richardson and Proctor[9]), approximately between 10^{11} and 10^{9} cm^2. sec.$^{-1}$ or expressed as eddy viscosities approximately between 10^{8} and 10^{6} g. cm.$^{-1}$ sec.$^{-1}$. In the ocean, the effects of the two lateral diffusion components (down-stream and cross-stream components) and of the vertical diffusion component have not been isolated and separately studied, but it is evident (at least in so far as the Caribbean basin is concerned) from a study of the vertical and horizontal gradients of the transferable substances[10]) that to be significant in diffusing substances the lateral turbulent components must exceed greatly the magnitude of the vertical diffusion component.

In connexion with the present investigation of turbulent transfer in the Caribbean basin it is desirable to consider the horizontal as well as the vertical gradients of the available identifying properties in order that comparison of their respective curvatures may furnish information on the magnitude of the horizontal diffusivity coefficients required to produce a measurable effect in their concentrations as a result of lateral diffusion. With this object horizontal and vertical distributions of oxygen, salinity, and temperature at the depth of the minimum oxygen concentration in the vicinity of stations 1499 and 1510 have been compared. The density of the minimum oxygen concentration in the area concerned is reasonably constant.

We are now concerned with the fundamental differential equation, regulating diffusion in the sea both by lateral and vertical turbulence, which may be written:

$$\varrho \frac{d\alpha}{dt} = \frac{\delta}{\delta Z}\left(A \frac{\delta \alpha}{\delta Z}\right) + \frac{\delta}{\delta x}\left(A_1 \frac{\delta \alpha}{\delta x}\right) + \frac{\delta}{\delta y}\left(A_2 \frac{\delta \alpha}{\delta y}\right) \tag{7}$$

The last two terms of the right-hand side referring to the down-stream and cross-stream components may be combined into an average value for the lateral component so that the equation would read:

$$\varrho \frac{d\alpha}{dt} = A \frac{\delta^2 \alpha}{\delta Z^2} + A' \frac{\delta^2 \alpha}{\delta N^2} \tag{8}$$

where A′ represents an average value for the two lateral turbulent components and $\frac{\delta^2 \alpha}{\delta N^2}$ the average horizontal gradient over a constant density surface. Values of $\frac{\delta^2 \alpha}{\delta Z^2}$ have been given previously for oxygen, $\frac{\delta^2 O}{\delta Z^2}$, salinity, $\frac{\delta^2 S}{\delta Z^2}$, and temperature, $\frac{\delta^2 t^\circ}{\delta Z^2}$, at the depth of the oxygen

[8]) Defant, Albert. "Die Zirkulation der Atmosphäre in den gemässigten Breiten der Erde." Geogr. Annaler, 3, pp. 209—265, 1921.

[9]) Richardson, Lewis F., and Proctor, Denis. "Diffusion over distances ranging from 3 km. to 86 km." Mem. Royal Meteorol. Soc., Vol. I, No. I, pp. 1—16, 1926.

[10]) See reference in footnote 2, p. 155.

minimum concentration between stations 1499 and 1510; and mean values for the second derivative of the horizontal gradient, $\frac{\delta^2\alpha}{\delta N^2}$, with reference to the same depth are given in Table 2.

Table 2.

Property	$\frac{\delta^2\alpha}{\delta N^2}$	Ratio: $\frac{\delta^2\alpha}{\delta Z^2} \Big/ \frac{\delta^2\alpha}{\delta N^2}$
Oxygen ... $\frac{\delta^2 O}{\delta N^2}$	$2 \cdot 15 \times 10^{-18}$ cm.^{3} g.$^{-1}$ cm.$^{-2}$	$\frac{\delta^2 O}{\delta Z^2} \Big/ \frac{\delta^2 O}{\delta N^2} = 1 \cdot 1 \times 10^6$
Salinity ... $\frac{\delta^2 S}{\delta N^2}$	$1 \cdot 75 \times 10^{-18}$ g. g.$^{-1}$ cm.$^{-2}$	$\frac{\delta^2 S}{\delta Z^2} \Big/ \frac{\delta^2 S}{\delta N^2} = 5 \cdot 7 \times 10^5$
Temperature $\frac{\delta^2 t^\circ}{\delta N^2}$	$6 \cdot 85 \times 10^{-15}$ deg. cm.$^{-2}$	$\frac{\delta^2 t^\circ}{\delta Z^2} \Big/ \frac{\delta^2 t^\circ}{\delta N^2} = 8 \cdot 4 \times 10^5$

Since the ratios of the second derivatives of mean vertical to mean horizontal gradients at the oxygen minimum concentration are of the order of magnitude of 10^6, a horizontal eddy diffusion coefficient having a value up to 10^5 may exist, and yet produce no measurable effect in the concentrations of the transferable substances. Thus, for example, the amounts of change in concentrations of oxygen, salinity, and temperature, calculated from a horizontal eddy diffusing coefficient of 10^5 C.G.S. units (based on data in Table 2) for the time interval as the water at the depth of the minimum oxygen concentration moves (along an isopycnal surface) from station 1499 to 1510 are given in Table 3. The results are also expressed as percentages of the observed change of concentration ($\alpha_2 - \alpha_1$) and of the change brought about by vertical turbulence (taking $A = 2 \cdot 8$ C.G.S. units). In all cases for this area, the horizontal diffusion which might be brought about by a lateral turbulent coefficient approximately 10^5 times the vertical component is slight.

Table 3.

Property	$10^5 \int_0^{2.3 \times 10^7} \frac{\delta^2\alpha}{\delta N^2} dt$	$100 \frac{\alpha \text{ lateral}}{\alpha \text{ observed}}$	$100 \frac{\alpha \text{ lateral}}{\alpha \text{ vertical}}$
Oxygen	$4 \cdot 95 \times 10^{-6}$ cm.^{3} g.$^{-1}$	—	3 %
Salinity	$4 \cdot 03 \times 10^{-6}$ g. g.$^{-1}$	4 %	6 %
Temperature	$1 \cdot 57 \times 10^{-2}$ deg.	4 %	4 %

Calculation of the amount of lateral diffusion brought about by a lateral eddy coefficient of 10^5 at the depth of the minimum oxygen concentration (calculated from data in Table 2) as the water moved from station 1499 to 1510 ($t = 2 \cdot 3 \times 10^7$ sec.).

Thus, while the above calculations do not necessarily demonstrate the existence of horizontal diffusion they do suggest that horizontal diffusion coefficients of order of magnitude of 10^5 may exist (at the depths concerned) without producing a measurable diffusion effect.

On the Explanation of the Oxygen Minima and Maxima in the Oceans.[1])

By

H. U. Sverdrup,

Scripps Institution of Oceanography, University of California,
La Jolla, California.

CONSIDERABLE attention has recently been given to the minima and maxima of oxygen content which occur over large parts of the ocean. In Figure 1 are entered three characteristic curves showing the oxygen content as function of depth. One curve (A 1226) is from the Gulf Stream area off the coast of the United States in latitude 35°07′N., one curve (M 156) is from the eastern part of the South Atlantic Ocean in latitude 15°19′S., and one (E.W. S, I, 8) is

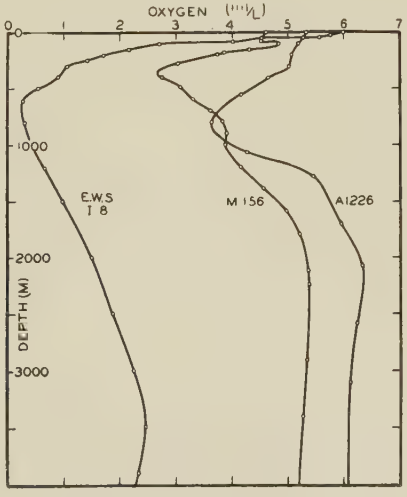


Fig. 1. The vertical distribution of oxygen in the Gulf Stream area (A 1226), in the eastern part of the South Atlantic (M 156), and off southern California (E.W.S. I, 8).

from the Pacific Ocean off the coast of southern California in latitude 32°56′N. All three curves show a well-defined minimum of oxygen between the surface and 1000 metres, and the curve from the South Atlantic Ocean also shows a secondary minimum below 1000 metres.

[1]) Contributions from the Scripps Institution of Oceanography, New Series, No. 22.

In the Atlantic Ocean, in the two selected cases, a maximum was present between 2000 and 2500 metres, and in the Pacific Ocean a maximum was present near the bottom.

Two different views have been advanced as to the cause of the minima and maxima, one which puts emphasis on the character of the currents, and one which considers the minimum as a result of the relation between oxygen replenishment to a given water mass and oxygen consumption within that water mass. The former view was first expressed by Jacobsen (1916) and has been adopted by Wüst (1935), who states (in translation) that "the intermediate oxygen minima in the stratosphere are principally dynamically conditioned, they characterize the nearly resting boundary layers between the different branches of the deep-sea circulation." Wüst, furthermore, assumes that the layers of oxygen minimum are characterized by minimum aeration (Schichten schwächster Durchlüftung) or, in other words, that at the oxygen minima the replenishment of oxygen by mixing processes and currents is at a minimum. Similarly, the layers of maximum oxygen content must be characterized by maximum replenishment of oxygen.

The other view has especially been advanced by Seiwell (1937), who thinks it probable that the biological activity within a water mass plays an important part in fixing the minimum.

It appears at present impossible to provide proof for any of these views, but the problem of the oxygen distribution can be formulated in such a manner that the implications of the two conceptions can be more clearly recognized. Calling the oxygen content σ, we have

$$\frac{d\sigma}{dt} = \frac{\delta}{\delta x}\left(A_x \frac{\delta\sigma}{\delta x}\right) + \frac{\delta}{\delta y}\left(A_y \frac{\delta\sigma}{\delta y}\right) + \frac{\delta}{\delta z}\left(A_z \frac{\delta\sigma}{\delta z}\right) \quad c$$

which means that the time-change of the oxygen content of a given water mass is equal to the amount which is added to the water mass by mixing processes minus the amount c which is being consumed in unit time. A_x A_y, and A_z represent coefficients of eddy diffusion. The equation is not valid within the photosynthetic zone, but we are concerned with conditions at greater depths only.

The above equation has, in the simplified form

$$c = A_z \frac{\delta^2\sigma}{\delta z^2} - \frac{d\sigma}{dt}$$

been used by Seiwell for determining the oxygen consumption at the level of the oxygen minimum. When making a general use of the equation it appears, however, better to consider what takes place within a fixed unit of volume and write

$$(1) \qquad \frac{\delta\sigma}{\delta t} = \frac{\delta}{\delta x}\left(A_x \frac{\delta\sigma}{\delta x}\right) + \frac{\delta}{\delta y}\left(A_y \frac{\delta\sigma}{\delta y}\right) + \frac{\delta}{\delta z}\left(A_z \frac{\delta\sigma}{\delta z}\right) - u\frac{\delta\sigma}{\delta x} - v\frac{\delta\sigma}{\delta y} - w\frac{\delta\sigma}{\delta z} - c$$

where u, v, and w represent the velocity components.

If no consumption took place the distribution of oxygen in the ocean would, under stationary conditions, be completely determined by the equation

$$\frac{\delta}{\delta x}\left(A_x \frac{\delta \sigma}{\delta x}\right)+\frac{\delta}{\delta y}\left(A_y \frac{\delta \sigma}{\delta y}\right)+\frac{\delta}{\delta z}\left(A_z \frac{\delta \sigma}{\delta z}\right)-u\frac{\delta \sigma}{\delta x}-v\frac{\delta \sigma}{\delta y}-w\frac{\delta \sigma}{\delta z}=0$$

adding the boundary condition that at the lower limit of the photosynthetic zone the water should be saturated with oxygen. Since we must assume that all water has at some time been near the surface, it would follow that the lowest oxygen values in subsurface depths would be as high as, or higher than, the lowest values in the photosynthetic zone. Actually, the minimum values are much lower and, therefore, consumption must take place. Since we have reason to assume that conditions are stationary, especially if we consider a large enough volume, we can state that in the ocean the net amount of oxygen which in unit time is supplied by physical processes to any given unit volume is equal to the amount which in the same time is consumed in the same volume by biological activity.

The replenishment in unit time is a complicated function, but if we knew the velocities, the oxygen gradients, and the coefficients of eddy diffusion as functions of the co-ordinates, x, y, z, of position in the ocean-space, we could represent the net physical rate at which oxygen is being replenished by a function of the form

$$f_r = f_r(x, y, z)$$

The consumption must be a function of a number of variables such as the respiration of organisms, the amount of available oxidizable organic matter, and the activity of the bacteria, which again may depend upon such factors as temperature and total amount of oxygen.

For the purpose of the following discussion we could represent the consumption as a function of the biological activity and the amount of oxygen, but it appears more desirable to introduce certain assumptions concerning the biological activity in order to draw attention to definite problems which may be studied by biologists and chemists. We shall, therefore, represent the rate at which oxygen is being removed by the function

$$f_c = f_c(\gamma, \sigma)$$

where γ represents the amount of oxygen-consuming organic matter (including living organisms) and σ, as before, is the oxygen concentration. This expression contains, as already stated, certain assumptions concerning the biological activity in the ocean and the further discussion depends greatly upon the validity of these assumptions.

The expression implies, for instance, the assumption that at any given point the consumption is independent of temperature and pressure. If these factors entered, we would have to write

$$f_c = f_c(\gamma, \sigma, \vartheta, p)$$

We shall in the following consider the derivative

$$\frac{\delta f_c}{\delta z} = \frac{\delta f_c}{\delta \gamma}\frac{\delta \gamma}{\delta z} + \frac{\delta f_c}{\delta \sigma}\frac{\delta \sigma}{\delta z} + \frac{\delta f_c}{\delta \vartheta}\frac{\delta \vartheta}{\delta z} + \frac{\delta f_c}{\delta p}\frac{\delta p}{\delta z}$$

and our assumption, therefore, implies that only the first two terms on the right-hand side are significant, or, since

$$\frac{\delta p}{\delta z} = g\varrho \neq 0, \text{ and generally } \frac{\delta \vartheta}{\delta z} \neq 0$$

that, at any given level,

$$\frac{\delta f_c}{\delta \vartheta} \text{ and } \frac{\delta f_c}{\delta p} \text{ are negligible.}$$

It appears possible to test the correctness of these assumptions. The specific conclusions which are presented in the following will depend upon the outcome of such tests, but the method of attacking the problem will retain its merits and the general conclusions as to the present hypothetical character of the explanations of the oxygen minima and maxima remain unaltered.

Concerning the character of the biological processes we shall, furthermore, assume that

$$\frac{\delta f_c}{\delta \gamma} > 0, \quad \frac{\delta f_c}{\delta \sigma} \geq 0, \tag{2}$$

or, in words, that the oxygen consumption increases with increasing amount of oxygen-consuming organic matter and that the oxygen consumption increases with increasing oxygen content or is independent of the oxygen content.

Equation (1) can now be written in the form

$$\frac{\delta \sigma}{\delta t} \equiv f_r - f_c$$

where the "identity" sign is used to emphasize that this is a logically identical relation between functions, and does not place any condition on the values of the variables x, y, z, t. Since conditions are assumed stationary with respect to time, time vanishes and we have

$$f_r \equiv f_c \tag{3}$$

$$\frac{\delta f_r}{\delta z} \equiv \frac{\delta f_c}{\delta z} \equiv \frac{\delta f_c}{\delta \gamma}\frac{\delta \gamma}{\delta z} + \frac{\delta f_c}{\delta \sigma}\frac{\delta \sigma}{\delta z} \tag{4}$$

$$\frac{\delta^2 f_r}{\delta z^2} - \frac{\delta^2 f_c}{\delta z^2} \equiv \frac{\delta^2 f_c}{\delta \gamma^2}\left(\frac{\delta \gamma}{\delta z}\right)^2 + \frac{\delta^2 f_c}{\delta \sigma^2}\left(\frac{\delta \sigma}{\delta z}\right)^2 + 2\,\frac{\delta^2 f_c}{\delta \gamma \delta \sigma}\frac{\delta \gamma}{\delta z}\frac{\delta \sigma}{\delta z} + \frac{\delta f_c}{\delta \gamma}\frac{\delta^2 \gamma}{\delta z^2} + \frac{\delta f_c}{\delta \sigma}\frac{\delta^2 \sigma}{\delta z^2} \tag{5}$$

From these equations it is immediately evident that Dietrich's formulation (1937) of the "dynamic" explanation of the oxygen

minimum contains conflicting statements. Dietrich writes (page 515), in translation, "This (explanation) is based on the still merely qualitative conception that, except within the plankton-filled upper layers, the oxygen consumption due to sinking detritus is relatively uniform along a vertical line. The layers of relatively small replenishment by advective movement must, therefore, be characterized by oxygen minima." These statements are obviously contradictory since we must assume stationary conditions and since in a steady state the replenishment must at all depths equal the consumption. If the replenishment at any level is at a minimum the consumption must be at a minimum at the same level and cannot be "relatively" independent of depth.

Returning to our main problem, a minimum or maximum in the oxygen distribution is present at a depth $z = z_m$, if at that depth

$$\frac{\delta\sigma}{\delta z} = 0, \frac{\delta^2\sigma}{\delta z^2} \gtrless 0 \tag{6}$$

Introducing the "dynamic" assumption that the replenishment of oxygen is at an extreme where the oxygen content has an extreme value, we have, when (6) is valid,

$$\frac{\delta f_r}{\delta z} - \frac{\delta f_c}{\delta \gamma}\frac{\delta \gamma}{\delta z} = 0 \tag{7}$$

$$\frac{\delta^2 f_r}{\delta z^2} = \frac{\delta^2 f_c}{\delta \gamma^2}\left(\frac{\delta \gamma}{\delta z}\right)^2 + \frac{\delta f_c}{\delta \gamma}\frac{\delta^2 \gamma}{\delta z^2} + \frac{\delta f_c}{\delta \sigma}\frac{\delta^2 \sigma}{\delta z^2} \gtrless 0, \tag{8}$$

the remaining terms of (5) containing $\delta\sigma/\delta z = 0$ as a factor.

It follows from (7) that either

$$\frac{\delta f_c}{\delta \gamma} = 0 \text{ or } \frac{\delta \gamma}{\delta z} = 0 \tag{9}$$

The former alternative, that the consumption of oxygen is (even locally) independent of the amount of oxygen-consuming organic matter (including living organisms), has been ruled out as improbable (equation 2); therefore the only remaining alternative is

$$\frac{\delta \gamma}{\delta z} = 0 \tag{10}$$

meaning that the amount of oxygen-consuming matter must be at a minimum or a maximum at the depth $z = z_m$.

The conditions from (8), dropping the now vanishing first term,

$$\frac{\delta f_c}{\delta z}\frac{\delta^2 \gamma}{\delta z^2} + \frac{\delta f_c}{\delta \sigma}\frac{\delta^2 \sigma}{\delta z^2} \gtrless 0 \tag{11}$$

respectively, for minimum and maximum must also be fulfilled, corresponding to minima and maxima of $f_r = f_c$. Since we have assumed

$$\frac{\delta f_c}{\delta \gamma} > 0. \frac{\delta f_c}{\delta \sigma} \geq 0 \text{ and since} \frac{\delta^2 \sigma}{\delta z^2} \gtrless 0$$

equation (11) will always be valid if

$$\frac{\delta^2\gamma}{\delta z^2} > 0 \text{ when } \frac{\delta^2\sigma}{\delta z^2} > 0$$

and

$$\frac{\delta^2\gamma}{\delta z^2} < 0 \text{ when } \frac{\delta^2\sigma}{\delta z^2} < 0$$

The "dynamic" assumption is, therefore, always valid if the amount of oxygen-consuming organic matter is distributed in such a manner that it shows minima or maxima at the depths at which the oxygen content shows minima or maxima, and it may be valid if extreme values of γ and σ coincide. Figure 2 gives a schematic representation of these conditions. It is not likely that such conditions exist, and this analysis, therefore, makes the "dynamic" explanation appear doubtful.

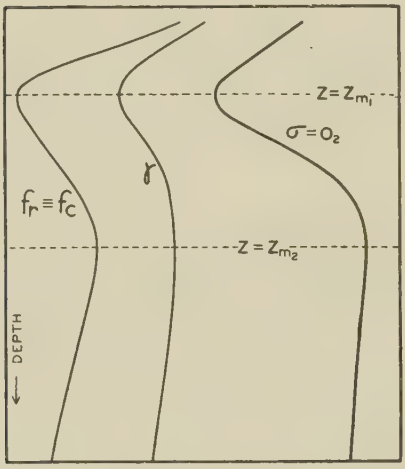


Fig. 2. Schematic representation of the distribution of oxygen-consuming organic matter, γ, which on certain assumptions must be present in the ocean if the layers of oxygen minima and maxima are layers of minimum or maximum replenishment (the "dynamic" explanation).

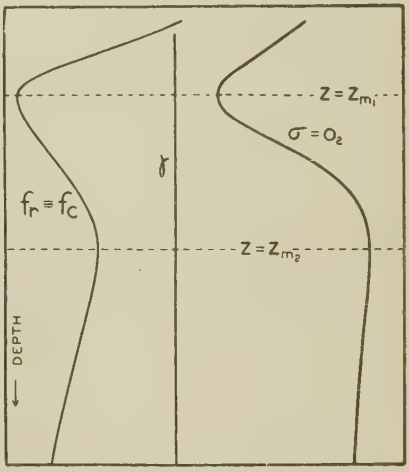


Fig. 3. Schematic representation showing that if the amount of oxygen-consuming matter, γ, is independent of depth, and if the consumption depends upon the oxygen content, the oxygen minima or maxima coincide with minima or maxima of replenishment (the "dynamic" explanation).

It should be added that the "dynamic" explanation may also be valid if the amount of oxygen-consuming organic matter is independent of depth and the oxygen consumption decreases with decreasing oxygen content. This case, which is presented schematically in Figure 3, is perhaps the case which Dietrich had in mind, although his words cannot very well be interpreted as describing such conditions. It is also of interest to observe that if, contrary to (2), the consumption is independent of the amount of organic matter but decreases with

decreasing oxygen content, minima and maxima in the oxygen distribution must coincide with minima and maxima of replenishment as required by the "dynamic" explanation. Thus, several possibilities exist, but the important conclusion is that the "dynamic" interpretation of the oxygen minimum layer places definite conditions on the distribution of biological activity in the sea, and the way is open for testing these assumptions by investigating whether the conditions are met.

Seiwell, on the other hand, has pointed out that it is not necessary to assume that the replenishment is at an extreme value at an oxygen minimum or maximum layer. From (4), (5), (6), (7) it follows that an oxygen minimum or maximum value will be present at the depth at which

$$\frac{\delta f_c}{\delta \sigma}\frac{\delta \sigma}{\delta z} = \frac{\delta f_c}{\delta z} - \frac{\delta f_c}{\delta \gamma}\frac{\delta \gamma}{\delta z} = 0 \tag{12}$$

$$\frac{\delta f_c}{\delta \sigma}\frac{\delta^2 \sigma}{\delta z^2} = \frac{\delta^2 f_r}{\delta z^2} - \frac{\delta^2 f_c}{\delta \gamma^2}\left(\frac{\delta \gamma}{\delta z}\right)^2 - \frac{\delta f_c}{\delta \gamma}\frac{\delta^2 \gamma}{\delta z^2} \gtrless 0 \tag{13}$$

If $\frac{\delta f_c}{\delta \sigma} \equiv 0$, it follows from (4) that

$$\frac{\delta f_r}{\delta z} \equiv \frac{\delta f_c}{\delta \gamma}\frac{\delta \gamma}{\delta z}$$

and in this case (12) is reduced to

$$\frac{\delta \sigma}{\delta z} \equiv \frac{0}{0}$$

meaning that our method of dealing with the question fails if the oxygen consumption is intrinsically independent of the oxygen content. We shall, therefore, add the assumption

$$\frac{\delta f_c}{\delta \sigma} > 0$$

and the general conditions for the existence of minima or maxima are then reduced to

$$\frac{\delta f_r}{\delta z} - \frac{\delta f_c}{\delta \gamma}\frac{\delta \gamma}{\delta z} = 0 \tag{14}$$

$$\frac{\delta^2 f_r}{\delta z^2} - \frac{\delta^2 f_c}{\delta \gamma^2}\left(\frac{\delta \gamma}{\delta z}\right)^2 - \frac{\delta f_c}{\delta \gamma}\frac{\delta^2 \gamma}{\delta z^2} \gtrless 0 \tag{15}$$

The equations are too complicated for a general discussion, but as a simple illustration we select

$$f_c = \gamma\, \varphi(\sigma) \equiv f_r(x, y, z)$$

Equations (14) and (15) then become

$$\frac{\delta f_r}{\delta z} \Big/ \frac{\delta \gamma}{\delta z} = \frac{f_r}{\gamma} \quad \text{and} \quad \frac{\delta^2 f_r}{\delta z^2} \Big/ \frac{\delta^2 \gamma}{\delta z^2} \gtrless \frac{f_r}{\gamma}$$

meaning that under these conditions the extreme values of oxygen will be found at the depths at which the tangents of the curves f_r and γ are proportional to the absolute value of the functions. Whether maxima or minima are present depends upon the curvature of the curves.

In order to introduce specific examples, we put

$$\varphi(\sigma) = k\sigma$$

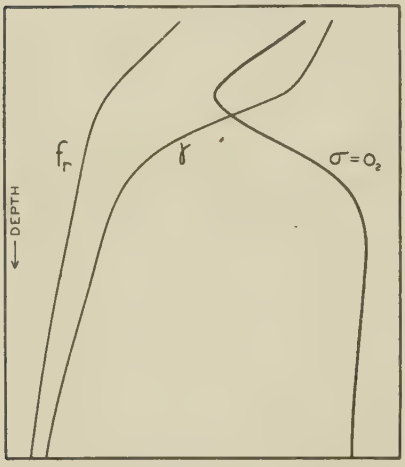


Fig. 4. Corresponding curves of oxygen, σ, replenishment of oxygen, f_r, and oxygen-consuming organic matter, γ, assuming the oxygen consumption to be proportional to σ and γ.

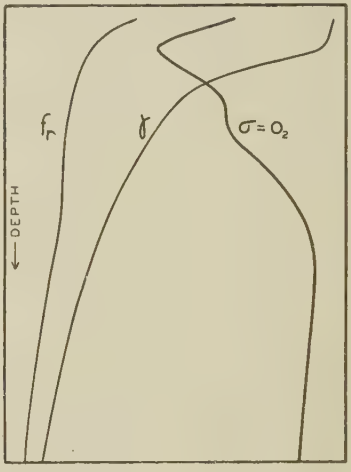


Fig. 5. Corresponding curves of oxygen, σ, replenishment of oxygen, f_r, and oxygen-consuming organic matter, γ, assuming the oxygen consumption to be proportional to σ and γ.

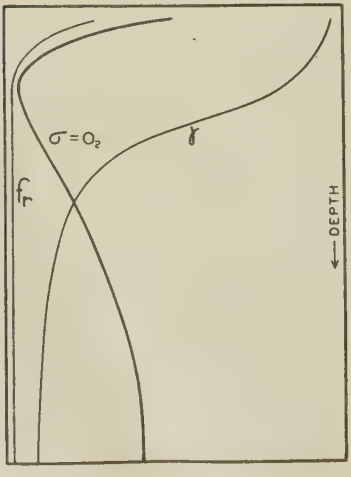


Fig. 6. Corresponding curves of oxygen, σ, replenishment of oxygen, f_r, and oxygen-consuming organic matter, γ, assuming the oxygen consumption to be proportional to σ and γ.

Figures 4, 5, and 6 have been prepared to illustrate different possibilities. The oxygen curves are similar to those shown in Figure 1 and the γ curves have been selected to give replenishment (or consumption) which decreases more or less regularly with depth, in agreement with the probability that deeper waters are in slower motion and have been away from the surface longer than the overlying layers. This is, under the supposed condition, possible only if γ has approximately the forms shown or, in other words, if the amount of oxygen-consuming organic matter decreases sharply below the level of the oxygen minimum.

The illustrations are not intended as explanations of the oxygen distribution, but they serve to emphasize that oxygen minima and maxima may not have any bearing on the structure of the system of currents. The assumptions as to the biological processes appear to be simpler than those which are implied by the "dynamic" assumption. Furthermore, by introducing a replenishment which gradually decreases with depth the distribution of oxygen in the ocean is brought into harmony with results of dynamic calculations which, at least in the Gulf Stream area, fail to show minimum velocities at the oxygen minimum.

Attention may also be drawn to the fact that in our simple examples we have assumed nearly the same distribution of oxygen-consuming organic matter in the Gulf Stream area and off the coast of southern California. Within the latter region the distribution of oxygen is accounted for by a much smaller replenishment, in agreement with the fact that the deep-water circulation of the North Pacific is very slow as compared to the deep-water circulation of the North Atlantic.

The most important result of the present discussion seems, however, to be that the two explanations imply different assumptions concerning the biological activity in the sea, and that the problem of the oxygen distribution in the ocean can be dealt with rationally only when we know more about this activity. It is to be hoped that biologists and chemists will be able to give answers to such questions as these: Can one, when dealing with the oxygen consumption in the ocean, introduce the concept, "amount of oxygen-consuming organic matter (including living organisms)?" Does the oxygen consumption depend upon this amount? Does this amount vary with depth? Does the oxygen consumption depend upon the oxygen content? Does the oxygen consumption depend upon other factors, such as temperature and pressure?

Explanations of the oxygen minima and maxima in the sea must remain hypothetical until some or all of these questions have been answered. At present it appears, however, that the "dynamic" explanation has the more arbitrary character.

Zusammenfassung.

Für die O_2-Minima im Ozean sind zwei Erklärungen gegeben. Die eine Erklärung (die "dynamische") betrachtet die Schichten des

geringsten Sauerstoffs als nahezu ruhende Grenzschichten zwischen den verschiedenen Zirkulationsgliedern, die andere betrachtet die Sauerstoffverteilung im allgemeinen als von der Beziehung zwischen Erneuerung bei Mischung und Advektion und Verbrauch bei biologisch-chemischen Vorgängen bedingt.

Es wird versucht zu zeigen, dass beide Erklärungen bestimmte aber verschiedene Annahmen über den Sauerstoffverbrauch voraussetzen. Die "dynamische" Erklärung scheint zur Zeit mehr willkürlich zu sein, aber jede Erklärung muss hypothetisch bleiben, bis Biologen und Chemiker einige oder alle der folgenden Fragen beantwortet haben:—

Ist es erlaubt, den Begriff "Sauerstoff verbrauchendes organisches Material (einschliesslich lebender Organismen)" einzuführen? Ist der Sauerstoffverbrauch von der Menge solchen Materials abhängig? Ist die Menge solchen Materials von der Tiefe abhängig? Ist der Sauerstoffverbrauch von der vorhandenen Sauerstoffmenge abhängig? Wird der Sauerstoffverbrauch von anderen Faktoren wie Temperatur und Druck beeinflusst?

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On the Application of the Statistical Theory of Space Distribution to Hydrographic and Fishery Problems.

By

H. J. Buchanan-Wollaston.

THE element of chance always enters into the distribution of organisms or other objects in space. Chance also influences all methods of collecting data about such distribution. Thus, statistical methods founded on theories of chance are applicable to space distributions, and it will be found that nearly all the ideas of ordinary statistics have their counterparts in space statistics.

Previous work on the theory of random migration will be referred to where necessary. Since, however, some of this is very complicated and the publications in which it appeared not always readily accessible, a short discussion on the simpler parts of the theory may be useful.

General Theory.

In general a space distribution of objects may be considered as due to movement of these objects from some known or hypothetical position. It is this movement into which the element of chance may be considered to enter. Movement is a vector quantity and chance may influence both quantity and direction of movement, which may be in one, two, or three dimensions.

It is necessary first of all to investigate the result of pure random movement of objects, and to simplify matters movement in one dimension only will be considered first. Random movement in one dimension may be considered as the sum of a very large number of minute equal movements, each of which is equally likely to be in one direction or in the opposite direction. Each movement element may be to the right or to the left, and the space distribution of m objects after n "chances" of movement will be given by the terms in the expansion

of the binomial $$m\left(\tfrac{1}{2}+\tfrac{1}{2}\right)^{2n}$$

in which expansion, however, there are always assumed to be n elements to the left, the consecutive terms corresponding to 0, 1, 2 .... elements to the right. The greatest number of objects will correspond to the centre term, where the movement elements left and right cancel each other out.

The spread of the moving objects is measured by $u\sqrt{\tfrac{1}{2}n}$, where u is the length of a movement element. The whole range of the distribution is given by the number of terms in the binomial; it extends from n units left to n units right, and including the centre space is $(2n + 1)$ units in length.

The number of movement elements, $2n$, is clearly proportional to the time during which the objects are subject to movement. Thus the spread from the centre is proportional to the square root of the time. The spread may then be written $\sqrt{kt}$, where k is a constant, which may, however, be different in different conditions.

It is implicit in the definition of random or chance movement that movement in one dimension is independent of that in another. Thus in two dimensions, naming the dimensions N —— S and E —— W, the distribution after time kt is given by the product of the terms of two similar binomials

$$\left(\tfrac{1}{2}+\tfrac{1}{2}\right)^{kt}\cdot\left(\tfrac{1}{2}+\tfrac{1}{2}\right)^{k't}$$

in which, however, k may be different from k'. The spread along one dimension is measured by $\sqrt{kt}$ and in the other by $\sqrt{k't}$. The radius vector from the centre to any position may be written

$$r = \sqrt{x^2+y^2}$$

where x and y are measured along N —— S and E —— W respectively. The spread in any direction may be written

$$\sigma_r = \sqrt{\sigma_x^2+\sigma_y^2} = \sqrt{(k+k')\,t}$$

and thus is proportional to the square root of the time. If, in the binomial, the exponent n be very large, the distribution is a very near approximation to the Normal Distribution, and the latter in practice may be used in place of the binomial. The space binomial, however large n may be, always has a limited range, since the unit u may be decreased as n is increased. The Normal Distribution has, strictly speaking, an infinite range unless the unit u is infinitesimal. The area contained between the curve of error and the base-line beyond, say, 4σ is, however, so small that in practice it cannot be taken into account and there is no measurable error in using "Normal" theory for chance distribution in space where the binomial is the logically correct theory.

In fishery research it is often the practice to study movement of objects in only two dimensions, since the depth dimension is so small

compared with the others. At present, therefore, discussion will be limited to movement in the horizontal dimensions.

Before proceeding to practical applications of statistical "space" theory, it is necessary to make some fundamental definitions covering the range of fishery research in which the theory is applicable. These definitions should apply to movements of water particles, of planktonic organisms, of drift-bottles and of marked fish, and may be extended so as to apply to the "spread" of salinity, phosphate ions, hydrogen ions, or even heat.

Definitions.

The following definitions appear appropriate to distribution in two space-dimensions:—

Centre of Distribution. The position from which movement is known or assumed to have taken place. The centre may be either a point or an open or closed line or curve. If the water from surface to bottom is considered, the centre is a line or a surface. As instances of Centres of Distribution may be given the position of liberation of a batch of marked fish or of drift-bottles, the position of greatest density in a plankton patch, an isohaline or isotherm considered as a surface extending from sea surface to sea bottom, the line across the mouth of a river, or the shore-line.

Spread. The process which results in a distribution of which the greatest density of objects subject to movement is at the centre, the density falling off continuously from the centre.

Random Spread from a Point. This results in a distribution surface conforming to a two-dimensional binomial or two-dimensional Normal curve of which the variance is proportional to the time during which the moving objects have been subject to chance movement. If the objects have been subject to movement for varying times (e. g., marked fish), the respective distances from the centre should be divided by the square roots of the respective times before the application of statistical tests for random spread.

Drift. The movement of the whole mass of objects in one direction while spreading.

Migration. This may sometimes take the form of drift as defined above, but will be defined here as a movement compounded of elements more likely to be in a direction away from the centre than towards is. The resulting distribution is ring-shaped, but the ring may not be circular nor need its centre coincide with the centre of distribution. It is best treated as a regression on direction and this regression may be significant or not significant. As a suitable regression equation the following is proposed:—

$$\log r = A_0 + A_1 \sin \theta + B_1 \cos \theta + A_2 \sin 2\theta + B_2 \cos 2\theta + \ldots .$$

in which r is the distance of any object from the centre of distribution and θ is the direction measured from an arbitrary zero direction. Only living organisms are subject to migration.

The above definitions correspond to statistical hypotheses and it is possible to apply statistical tests of the usual kinds to see whether these hypotheses are contradicted by the data or may reasonably be accepted. Before giving examples of such tests I propose, however, to illustrate what may be a useful application of the theory of chance movement to distribution of salinity with a view to disentangling the effects of random spread of water particles from those due to drift or residual current, and thus to give a picture of the latter.

Application of the Theory of Random Spread to Mixing Bodies of Water, with a Method of deducing Residual Flow from Salinity Distributions.

The theory of random spread may be of service in the interpretation of isohaline charts in terms of currents, more particularly in regions lying between two large masses of water, each of which is of fairly even salinity. The regions in question may be called mixing areas and the flow of water in such a mixing area is mainly vortical. The average movement of water across the mixing area is nil. Each "terminal" water may be considered as bounded by an isohaline, the salinity for a considerable space behind this being even enough to make it reasonable to assume that it all has the salinity of the bounding isohaline. The isohaline is chosen with this in view.

Assume now that the two waters, A and B, are placed with a surface of each in contact with a surface of the other, and assume that both masses are stirred throughout by relatively minute vortices. The particles of each mass are now taking part in a purely random movement. To simplify the case this movement will be considered to be in the two horizontal dimensions only. The particles of one water mass are taking part in a random movement in a space composed of particles of the other. If the centre of distribution were the dividing surface only, the proportional number of particles of mass A in mass B, at any given distance from the surface, could be represented by a set of equal terms of a two-dimensional binomial, the number of B particles at the surface in question being represented by unity minus the terms in question. If the normal curve be employed as an approximation to the binomial, the proportional number of A particles at the distance x measured normally from the dividing surface could be represented by an ordinate of the curve of error, the number of B particles by unity minus that ordinate. The distance x would be measured in terms of $\sqrt{kt}$, which corresponds to the standard deviation of the ordinary curve of error. In this expression k is a "mixing coefficient", t being the time during which mixing has been taking place.

Now, since the terminal waters have extension behind the bounding isohaline, the proportion of A in B is not the contribution of a surface but of a solid body. The proportion may be represented by the sum

of the ordinates of a large number of infinitesimally spaced curves of error in series one behind the other. Thus the proportion of A in B may be represented approximately by an ordinate of the "ogive" or integral curve of error.

As the two bodies of water mix, the bounding isohalines will be pushed further and further away from each other. In fact, if mixing actually follows the normal ogive, *some* water from each mass will penetrate to the greatest possible finite distance into the other mass. We need not concern ourselves, however, with this, since the true theory of mixing is assumed to be binomial, the normal curve being merely used as an approximation to the binomial. We may consider for practical purposes that the ogive is bounded by x equal to, say, 3σ or $3\sqrt{kt}$. The ordinate of the ogive at this point is equal to 0·9986, and this may be considered as unity for purposes of argument. After the bounding isohalines have been pushed back to certain positions relatively to the substratum, it is found that they do not retire any more but maintain their positions. This condition may possibly arise in nature if the two water masses are in motion *along* the bounding isohalines. The water between the two bounding isohalines may be considered as a mixing area. If each salinity at any point in the area were expressed as the fraction of the salinity of the nearer terminal water which, compounded with the complementary fraction of the salinity of the other terminal water, would give the observed salinity, then isohalines drawn from the salinities would be spaced out as would ordinates of the ogive — ordinates having a common difference. They would not be equally spaced relatively to the substratum, since measurements on the substratum are measurements on the abscissae of the spatial curve of error, not measurements on the axis of ordinates.

It is a simple matter to replace ordinates of the ogive by the corresponding abscissae. If this is done and lines through equal abscissae be drawn, these x-isolines will be equally spaced out over the substratum if there are no residual currents in the mixing area.

Now it is quite clear that the speed of a residual current large enough to be of interest from the fishery point of view is of quite a different order of magnitude from the speed of mixing of the terminal waters, whatever the mixing coefficient may be. It seems very unlikely that particles of one water mass will spread into the other at a rate measurable in miles per day. Variations in the rate of spread will be of an even smaller order. Thus the value of the mixing coefficient may be neglected in interpretation of isoline charts in terms of currents unless extreme accuracy is required.

We shall find, indeed, that the interpretation of isohaline charts in terms of residual currents may be carried out entirely independently of knowledge of the value of the mixing coefficient. The relative order of magnitude of the speed of spread of one water into the other compared with the speed of the residual currents need not enter into the case at all.

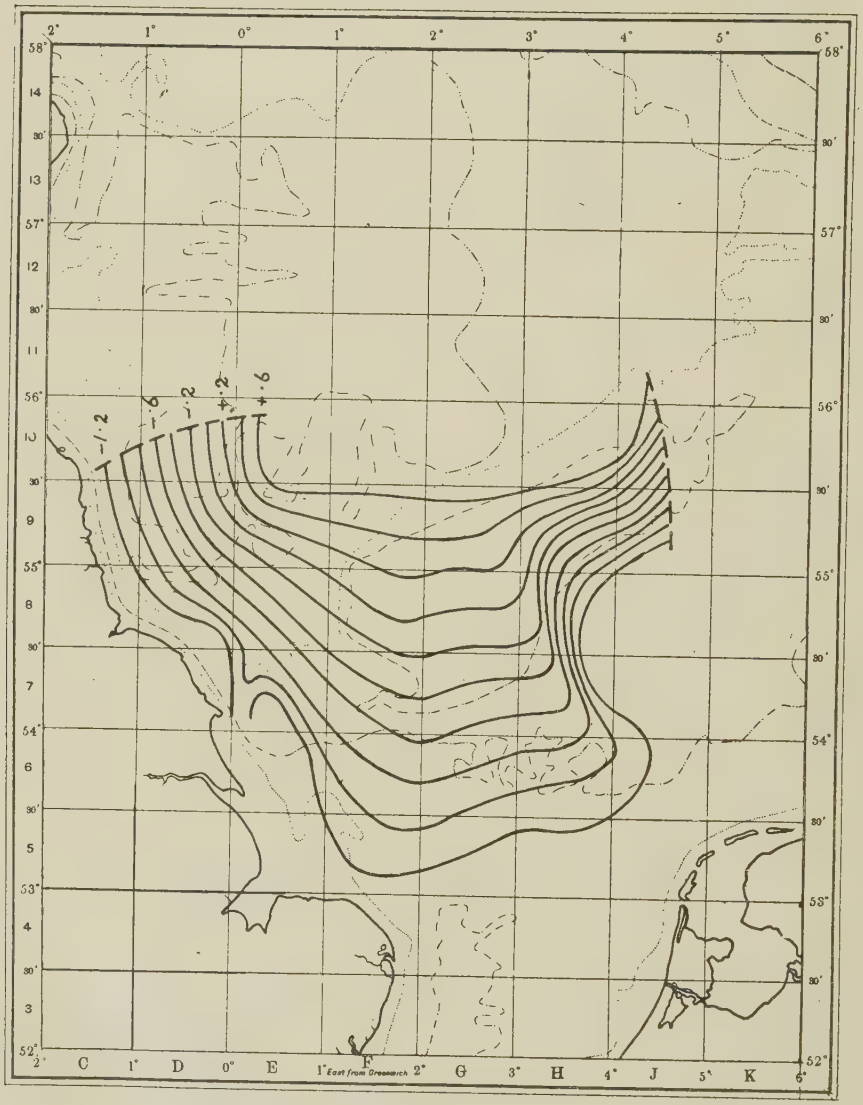

Chart 1.

Let us assume that the area on a chart between two bounding x-isolines has been equally divided by x-isolines. Chart 1, which will be fully explained later, is an example of this division. The bounding isolines are $x = +0{\cdot}6$, the northern line, and $x = -1{\cdot}2$, the line surrounding the area to the west, south, and east. For the present part of our argument the water extending to the northward of $x = +0{\cdot}6$ is assumed to have a fairly even and high salinity, the water outside $x = -1{\cdot}2$ has a fairly even but low salinity. Each water is assumed

Chart 2.

to have sufficient spatial extension for the ogive law to hold good approximately.

There is an interchange of water across the area enclosed in the bounding lines, this interchange maintaining the conditions shown by the x-isolines. The speed of this interchange is irrelevant to the present discussion, the movement of particles of one water in one direction being exactly balanced by that of particles of the other water in the opposite direction. Every small body of water in the region is the

result of continuous opposite movement of particles: it has only instantaneous identity. We can, however, say that any water of a given salinity lying between the bounding lines "belongs" to a particular slice of the area.

If it can be assumed that the shape of the bounding lines is due to movements outside them, then Chart 1 is a "no-current chart", the waters represented in it being merely in a state of equal and opposite interchange. It is probable that the conditions shown by this chart cannot possibly occur in nature. It is used merely as a basis for interpreting an actual x-isoline chart.

In addition to interchange of water across the isolines, which gives these their position, there is also equal and opposite interchange along the isolines. These movements are the components of the complete interchange which is going on equally in all directions. The particles passing outwards through the bounding isolines are, however, assumed to be carried away by the currents maintaining the terminal waters at a constant salinity.

Chart 2 is an x-isoline chart drawn from the surface salinity data used by Lumby and Carruthers in a paper of 1928[1]). The salinities 35·13 and 34·23 were chosen as the salinities of the two terminal waters. This choice may not be the best and may have to be modified in the light of further experience, but will serve in the explanation of the present method.

For the construction of Chart 2 every salinity was first replaced by the fraction of one terminal salinity which, combined with the complementary fraction of the other would give the observed salinity. The fraction was then considered as an ordinate of the ogive and the corresponding value of the abscissa, x, was entered on the chart. As Pearson's table[2]) of the ogive was used and in this 0·5 is added to each ordinate, the fraction of the complete range of 0·9 $^0/_{00}$ to which any salinity corresponds was measured from the salinity furthest from the observed salinity. For example, a salinity of 34·82 or 34·23 + 0·59 corresponds to the fraction 0·59 ÷ 0·9 or 0·65 of the range. A mixture of 65 $^0/_0$ of water of 35·13 $^0/_{00}$ with 34 $^0/_0$ of water of 34·23 $^0/_{00}$ gives water of 34·82 $^0/_{00}$. The fraction 0·65 is looked up under $\frac{1}{2}(1 + a)$ in Pearson's table and we find the corresponding value of x to be 0·4. For salinities below the middle salinity, 34·68, x-values were considered to be negative. Isolines were then drawn at convenient intervals for x.

Our purpose is to interpret every part of the isoline chart in terms of currents. It is therefore essential that the isolines be very carefully drawn. For Chart 2 every transverse line of stations was taken as an abscissa, the corresponding x-values being erected as ordinates. The ordinates for each line were joined by a smooth curve without sharp

[1]) Lumby, J. R., & Carruthers, J. N. "An Experiment dealing with the Interpretation of Salinity Distribution Charts." Journ. du Conseil, III, No. 2, 1928.

[2]) Table II. Pearson's Tables for Statisticians and Biometricians, Vol. I.

changes of curvature. Horizontal lines through the x-values chosen for the isolines were then drawn across the curves and the abscissae of the points at which the horizontal lines cut the curves were noted on the chart. Very careful note was taken whether any curve *nearly* rose or *nearly* sank to a horizontal line which it did not actually cut and the positions at which these near approaches occurred were marked on the chart. Each isoline was drawn through all the corresponding cutting points, and its shape between these points was determined by the positions of the aforesaid approaches between curves and horizontal lines. If these points are borne in mind, the personal factor is almost completely eliminated in the drawing of isolines.

It is useless to attempt to draw isolines of high values of x, positive or negative, since they lie so very close together. In Chart 2 x-isolines have been drawn at intervals of 0·2 from $x = +1$ to $x = -1{\cdot}2$. Unfortunately the voyages did not extend far enough to the north to give continuous isolines beyond $x = 0{\cdot}6$. This line is fairly continuous. It shows certain tongues pointing to the southward and indicating residual currents. Therefore it was assumed that the isoline would have a smooth form but for these currents. The assumed "no-current" form of $x = +0{\cdot}6$ is shown in Chart 1.

Assuming that Chart 1 gives the "no-current" positions of the isolines, the difference between their positions in Chart 1 and in Chart 2 is due to residual currents. Currents *along* the isolines will not have any effect on their form. Thus, the components of current along the isolines cannot be interpreted from the form of these lines, except indirectly through observation of the bends in isoline tongues.

The following method of interpretation of x-isolines in terms of current is intended as a suggestion only. Possibly it affords a useful basis upon which a complete method may be developed by modification in the light of further experience. It is largely of an empirical nature and its success depends on the degree to which its results agree in any case with direct current measurements and drift-bottle results. If the method be so adjusted in each case that the deduced currents in those parts of the area investigated in which direct current measurements are made agree with these, it is felt that the deductions of currents in the remainder of the area must be fairly reliable. If such adjustment can be made in a simple manner the method will be very useful, since it yields results covering the whole of the area investigated, and in great detail. It is also free from the personal factor, in that the adjustments necessary are of a rigid kind and may be defined precisely. The method is founded on the following theory.

An isoline may be considered as representing a single row of particles of water A divided by particles of water B. The particles may undergo four kinds of movement. The first is random movement in all directions. Clearly this does not change either the position or the shape or the value of the isoline in any way. The second movement is translation of the strip without endways movement. By this the isoline is moved continually to new positions and cannot take a permanent position. The third kind of movement is endways along the

isoline. This does not change the shape or position or value of the isoline. The fourth movement is caused by extension of the isoline by greater translation of some parts than of others. The original A particles are drawn apart, but their places are immediately taken by others from the water on each side in such a way that the degree of the isoline is not affected. All these motions are combined, but by resolving the complete motion into its components it is possible to study them separately or in any desired combination.

As stated earlier Chart 1 represents a condition of mixing in the absence of residual current. This chart will, however, equally well represent a condition of mixing combined with any set of residual currents which flow entirely along the isolines. This is self-evident. Let us assume the simplest kind of flow along the lines, a steady flow down the lines on the west side and out at their eastern ends. The flow may be visualized as if it were that of an elastic solid. This may be illustrated by dividing each isoline into the same number of equal parts, and drawing an arrow from each point of division to the next adjacent point on the same isoline. The arrows will be longer in the longer isolines than in the shorter, the flow indicated therefore being greater in the outer than in the inner parts of the system. The stream as it approaches the eastern ends of the isolines and as it leaves their western ends is assumed to be such that a line of floating objects represented by the broken line on the west will lie along the broken line to the east after being carried round the system. Since the mass of moving water is continuous, as in a river of varying width without tributaries, the c u r r e n t, or speed of water through a point, must be less where the isolines are far apart than where they are close. The length of an arrow is not therefore proportional to current, but to transport of water across unit surface, representing mile-gallons or mile-tons per day, not miles per day. We shall refer to this transport of water as "flow".

For studying flow normal to isolines, that is to say, along tongues in them, we shall assume at first that there is no general uni-directional flow along the lines. Chart 1 is now a no-current chart. Take a row of A particles in B particles represented by any isoline in Chart 1. As there is no flow in a particular direction along the isoline the particles at the positions of the broken lines in Chart 1 do not move. Let the row of particles represented by the isoline be extended, or in other words, let the isoline be stretched so that its length between the broken lines is much longer than before. The row must now be filled up by A and B particles from the water on either side of the isoline, the original particles being further separated than before. This separation can be represented by dividing the isoline into as many equal parts as the original line. If the division points on the original isoline are joined to corresponding points on the new stretched line by arrows, these will represent the amount of water supplied to the new line. The arrows represent the trajectories of particles which were equally spaced out when they crossed the position of the corresponding "no-current"

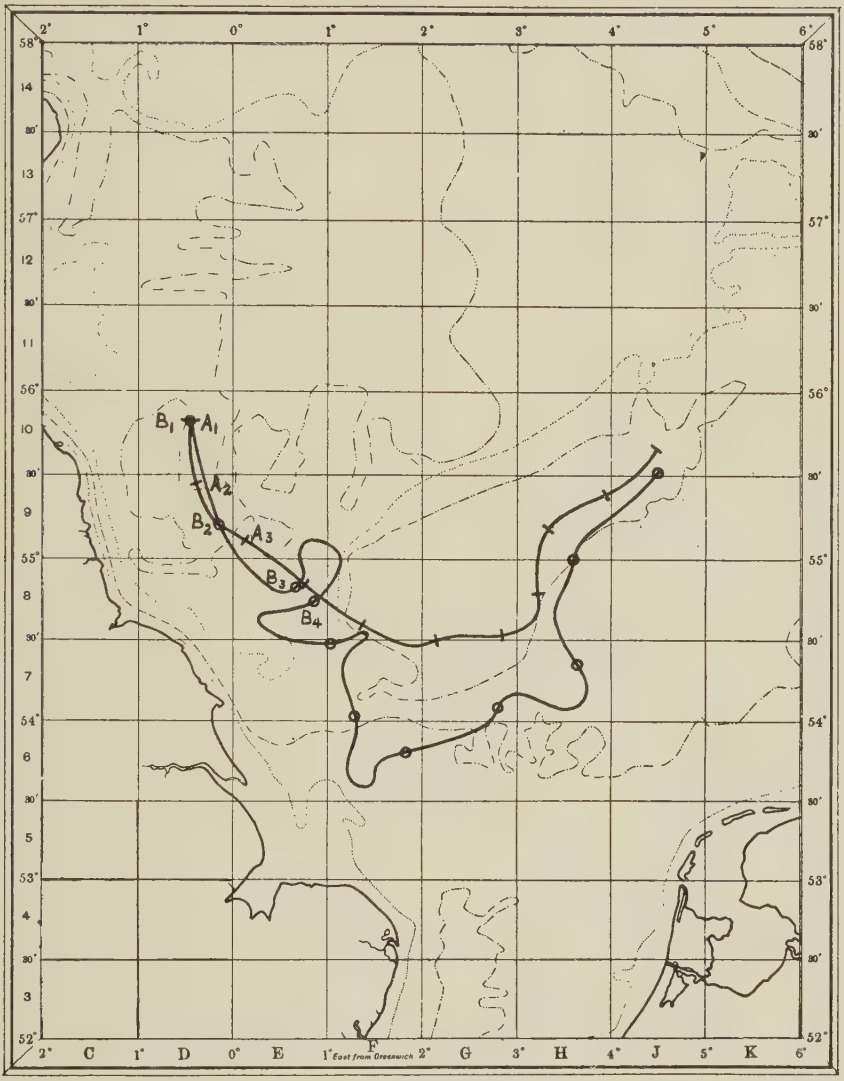

Chart 3.

isoline. The supply is continuous and therefore the lengths of the arrows are proportional to the transport of water between a strip of water at the position of the original line and the new line. Since outflow is equal to inflow, the new water supplied must be assumed to flow out along the stretched isoline in both directions. This does not imply that there is no flow across the isoline, since arrows from other strips will cross it and turn out further "down stream". This is discussed in greater detail below.

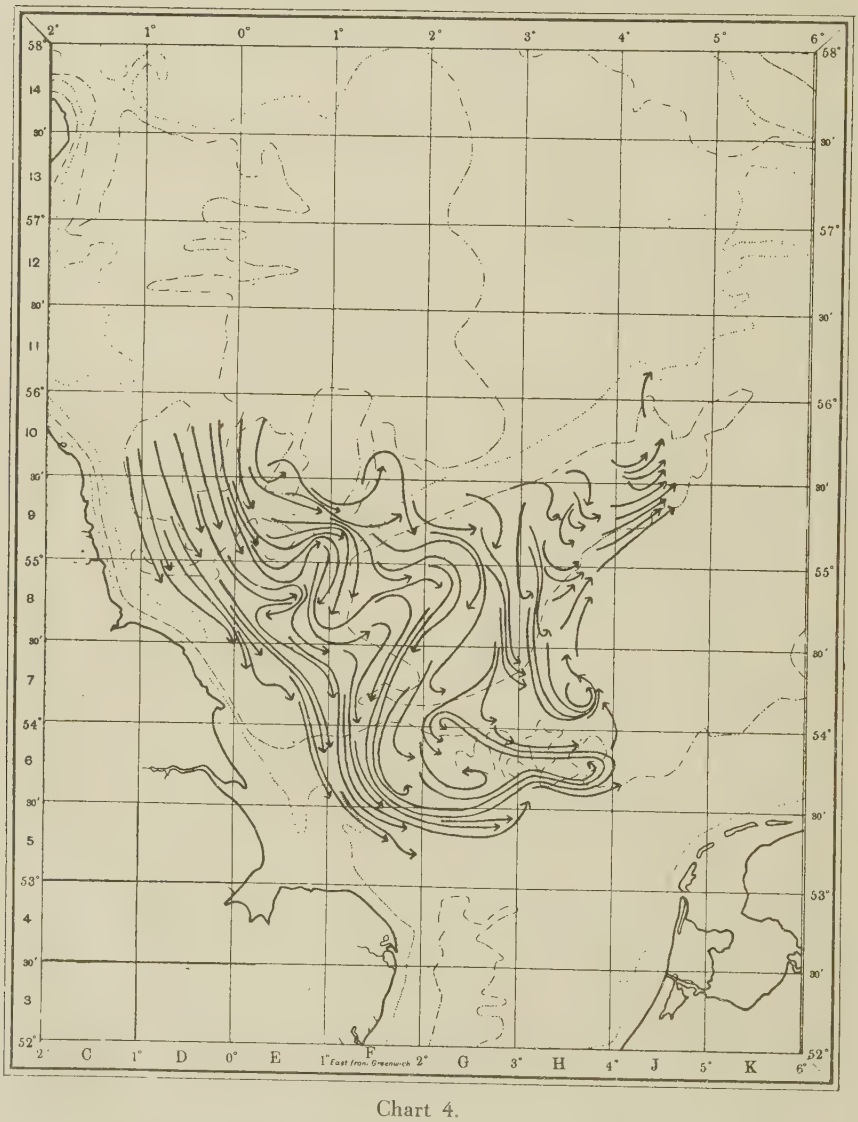

Chart 4.

Let us now study Chart 2 in the way indicated for the purpose of deducing the residual flow in the area covered by x-isolines. Lumby and Carruthers, in their paper already mentioned, include some data from direct current measurements. Although these were made at 20 metres depth and are current measurements, I consider that a surface flow chart should show rough agreement with these. A trial chart was drawn on the assumption that there was equal outflow from both ends of the isolines and it appeared certain that the system shown did not agree sufficiently well with direct current observations. It was

therefore assumed that there was a flow along the isolines from west to east, this flow being proportional to the extension of the isoline to which it applied.

For a first trial it was assumed that the transport of particles could be represented by joining division points in each unstretched isoline, not to corresponding points in the stretched line, but to the next adjacent points to the east, thus taking account of flow to the isoline and of unidirectional flow along it. For this, each isoline of Chart 1 was divided into ten equal parts with the aid of a rotameter, the corresponding isoline of Chart 2 being also divided in the same way. A separate chart was used for each pair of isolines. A chart on tracing paper was then laid over each of these separate charts in turn and arrows were drawn on the tracing chart joining the division points in the way described. This is illustrated in Chart 3, A_1 being joined to B_2, A_2 to B_3, A_3 to B_4, and so on, by arrows. These arrows were not allowed to cross each other and their heads were drawn pointing along the stretched isolines towards the east, that is to say, left-handedly. It was often found that arrows had to be redrawn so that they should not cross others drawn subsequently. No other rules were made for drawing the arrows and the influence of the personal factor was limited to imposing a slight amount of parallelism on adjacent arrows.

Chart 4 shows the results of the procedure described. The length of the arrows is supposed to show the proportional amount of water transported in unit time, and their direction the direction of transport at all points along them. Where an isolated arrow shows a sharply recurved head this indicates merely a slight component in the main stream towards the point of the arrow, the general stream carrying on along the direction of adjacent arrows. A set of closely adjacent arrow-heads must be understood as indicating the general direction of the flow.

The indicated estimates of flow agree sufficiently well with those shown by direct current observations, and it is thought that Chart 4, therefore, may give a general idea of the whole current system. The choice of strength for the flow along the isolines was, however, purely arbitrary, since no direct observations were made in the appropriate places for determining these. It seems, therefore, necessary to regard the chart as illustrating a suggestion which may be useful in future cases.

Assuming Chart 4 to give correct readings of flow purely for purposes of argument, we see that the outflow from the eastern ends of the isolines is much less than the inflow on the west. There must, therefore, be a flow out of the system somewhere. The lines suggest that this occurs at the south-east corner. A study of the isolines beyond $x = -1{\cdot}2$, which have not been included, shows this to be the case. The system is not completely closed and some water escapes into the neighbouring system at the position indicated.

The method described may be useful for the purpose of estimating

the effect of a strong wind from a particular quarter. The wind during the voyage on which the data illustrated in our charts were taken was very variable in direction, and not very strong at any time. It may be that Chart 3 shows what might be expected to occur with a fairly strong north-west wind, not what did in fact occur. It might be possible to estimate the effect of a strong north-east wind by applying a flow from east to west along the isolines.

Quantitative Determination of the Nitrogen in the Particulate Matter of the Sea.

By

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Introduction.

THE principal steps in the nitrogen cycle in the sea are:— living organism, dead organism, ammonia, nitrite, nitrate, living organism. A thorough understanding of the circulation of nitrogen in the sea must be based upon the quantitative relationships involved in these various steps. So far, the soluble substances are the only ones which have received much attention, and during the last decade considerable information has been accumulated concerning their quantitative occurrence in various seas, seasonal fluctuations, etc. But the nitrogen fixed in the living and dead organisms floating in the oceans has been largely neglected, at least in so far as direct determinations are concerned. A start has been made, from a laboratory standpoint, to establish a relation between the nitrogen in soluble form and that in the particulate matter of sea water (von Brand, Rakestraw & Renn, 1937), but attempts to calculate the nitrogen occurring in organisms, from the soluble nitrate found before, and during, the flowering season of diatoms in the sea give results of doubtful value. The movements of water masses and the turnover of the organisms make it obviously impossible to determine the amount of nitrogen in the particulate matter in any part of the sea, at a given moment, from nitrate data taken at intervals of several weeks or months. Furthermore, conditions in this respect in the deeper water layers can certainly not be understood from the study of soluble substances alone; a direct determination of the nitrogen bound in the particulate matter is necessary. Since only limited amounts of water can be secured from the deeper layers, and since the amounts of particulate matter occurring there are very small, two difficulties have thus far made the direct approach difficult. One is the difficulty of getting the particulate matter out of the samples in a form suitable for analysis, and the second is the determination of such small amounts

[1]) Contribution No. 163 of the Woods Hole Oceanographic Institution.

of nitrogen with sufficient accuracy. In recent years these difficulties have been overcome. The methods, though not ideal, have now been tested sufficiently to warrant a review of them and of the results so far obtained. The following account includes previously published data, as well as new results obtained at Woods Hole during the summer of 1937.

Methods.

1. Securing the Samples.

The analytical methods have thus far not been adapted to use on board ship. The water samples must therefore be prepared in such a way as to preserve the particulate matter and avoid contamination as far as possible. In those parts of the sea so far investigated, the sample brought up in one ordinary Nansen bottle contains enough particulate nitrogen for duplicate analyses. The danger of contamination is less if the whole content of the water bottle is used exclusively for the nitrogen determinations, rather than an aliquot taken from several Nansen bottles. If other analyses are to be made at the same station, the water necessary for them should be taken from another water bottle fastened near the first one. The water sample should be emptied into the storage bottle (carefully cleaned and preferably glass stoppered), using a small amount to rinse it. Then 20 ml. of concentrated formalin are added and the bottle closed.

2. Concentration of the Particulate Matter.

Investigations in recent years have clearly demonstrated (Steemann Nielsen, Schmidt-Ries, 1936) that simple centrifugation is not sufficient for quantitative determinations of the nannoplankton. The method giving the most reliable results is Utermöhl's sedimentation method. His procedure, however, is for certain reasons not suitable for quantitative chemical work. The only other method giving similar results is the concentration method of Steemann Nielsen and v. Brand (1934). The principle is to precipitate calcium and magnesium hydroxides in the sea water by addition of alkali, which, by centrifugation, carry down the particulate matter quantitatively. The technical details of this method are as follows:— One litre of the sample is poured into a graduated cylinder of one litre capacity, after having cleaned both the cylinder and the neck of the bottle carefully. Then 5—10 ml. of a 5 per cent. KOH solution are added. The resulting precipitate is stirred thoroughly with a clean glass rod. It is essential that the precipitate be distributed completely through the whole water column. In my experience this is a point often neglected, and if not carried out properly large losses result. It seems not impossible that the unfavourable results reported by Bernard and Fage (1936) are due to the neglect of one of the minor details of the method. For this reason it is described here in greater detail than in the original communication. The graduated cylinder is covered with a clean watch-glass and the precipitate allowed

to settle for 12 hours or more, during which time the sample should not be moved. After this, the level of the precipitate will be somewhere between the 50 and 100 ml. mark. The clear, supernatant liquid is then siphoned off. The siphon should not extend below the 200 ml. mark. When the level of the water has fallen to the 220 or 230 ml. mark, the siphon is carefully removed and the precipitate stirred. A few ml. of 5 per cent. HCl are added in order to reduce the amount of the precipitate. The exact amount of HCl is of no importance; the essential point is that the remaining precipitate should be voluminous enough to give the water a cloudy appearance after dispersion. The dispersed precipitate is transferred quantitatively into a centrifuge flask of 250 ml. capacity and centrifuged for about 5—10 minutes at high speed. The precipitate is then at the bottom of the flask in a compact gelatinous mass, from which the supernatant liquid can be poured off easily without loss of precipitate. Then enough HCl is added, drop by drop, to dissolve the precipitate completely, mixing with a clean glass rod meanwhile. The resultant clear solution is transferred quantitatively to a 50 ml. centrifuge tube and enough KOH solution is added to produce a precipitate again, in such a quantity that the solution is distinctly cloudy when thoroughly stirred. The centrifugation is repeated. The precipitate now contains all the particulate matter. The supernatant liquid is decanted into another centrifuge tube and KOH solution again added, as before. Another precipitate is obtained, similar to the first one, which is also separated by centrifugation, discarding the remaining solution. Although this second precipitate contains none of the particulate matter it is carried through the subsequent analysis along with the first one, as a control. It always contains a small amount of nitrogen, of unknown but non-particulate origin.

During the time the tubes and graduates are standing they are carefully covered with watch-glasses. Finally, both precipitates are suspended in "nitrogen-free" distilled water (see below), made up to the desired volume, and stirred. They are then ready for the actual analysis.

3. Nitrogen Analysis.

The method was originally proposed by K r o g h and K e y s (1934) for determination of the dissolved organic nitrogen in sea water. Its adaptation to the determination of the nitrogen content of particulate matter in the sea has been described by v o n B r a n d (1935), where details of the method will be found. It will be sufficient to describe here the general principles and to emphasize some points, which may appear unimportant at first glance, but which in my experience are essential for consistent results. The outline of the method is as follows:— The material to be analysed is heated to about 500°C. in a silver tube in the presence of alkali, but no oxygen, while passing through the tube a stream of hydrogen free from oxygen and ammonia. The organic nitrogen present in the particulate matter is transformed

into ammonia which is determined according to the method of Teorell (1932) as modified by Krogh (1934). The hydrogen must be of high purity. Simple purification by bubbling it through sulphuric acid and passing it over heated copper proved to be sufficient for the hydrogen obtainable in Denmark. But "electrolytic" hydrogen, obtainable in the United States, gave high and very irregular blank values under these conditions. This could only be purified satisfactorily by passing it successively through one wash-bottle containing chromic acid, three of strongly alkaline permanganate solution, one of sulphuric acid, and finally over heated platinum gauze, a procedure similar to that used by Krogh and Keys (1934). The presence of impurities in the hydrogen is indicated by the permanganate solution turning green in a few days, after which it must, of course, be renewed.

I am in entire agreement with Krogh and Keys that one of the principal difficulties of the method is to get distilled water sufficiently pure. This must be used for the suspension of the precipitates before analysis, and to wash the inlet of the silver tube. Following Krogh's suggestion, I use deep sea water, which is first distilled directly, then again from strongly alkaline permanganate, and finally from dilute phosphoric acid. During the last distillation a stream of air, free from NH_3 and CO_2, is passed through the distillate. Such water gives blank values distinctly higher than distilled water prepared from tap water in Copenhagen. But since they proved to be consistent, this difference was not thought serious. The preparation of "nitrogen-free" water must, in any case, be given careful attention, but its source and preparation are questions which can only be answered in the light of local circumstances.

In the course of a routine analysis I always ignite 1 ml. of material (either from the sample of particulate matter or the "control" precipitate) and 1 ml. of water used for washing the inlet of the ignition tube. Since it is not convenient to bring the precipitates to exactly two ml., which are required for duplicate analyses, I use the following procedure:— The centrifuged precipitates have usually a volume between 0·3 and 0·5 ml. About 2 ml. of nitrogen-free water are added and, after stirring, duplicate analyses are carried out on 1 ml. portions. Finally the fluid remaining in the centrifuge tube is measured by sucking up into a graduated pipette, and the total amount of nitrogen in the precipitate is calculated. If there was too much nitrogen in the first samples for a satisfactory analysis, the small residue can be used for another determination.

4. Accuracy and Limitations of the Method.

The accuracy of the method is of course not as great as that of a macro-Kjeldahl determination. Duplicate determinations generally agree within 10 per cent., although somewhat greater differences may occur when very small amounts of nitrogen are present (von Brand, 1937).

A distinct drawback of the method is the fact that erratic results are obtained when there is so much nitrogen present that it completely exhausts the hypobromite used in the ammonia determination. There may, indeed, be little indication that this has taken place, and the apparent ammonia values will generally be lower, the higher the excess of ammonia. This danger was known to Teorell (1932). If there is any doubt about the validity of one determination, another one with a smaller amount of material, say half of it, should be performed. If it yields appreciably more than half, or even more than the whole amount of nitrogen found in the first determination, then this first one is incorrect, for too large a sample has been used. No general directions can, therefore, be given as to the amount of water to be used for the first precipitation, or, what amounts to the same thing, the amount of nitrogen-free water in which the material is finally suspended. Water samples of the following volumes, taken from the localities indicated, proved satisfactory for single analyses, using a hypobromite solution of twice the strength originally recommended by Krogh (1934): deep sea (lower depths), 500 to 1000 ml.; deep sea (upper depths), 250 ml.; Gulf of Maine, 100 to 200 ml.; water adjacent to Iceland, 20 to 200 ml.

The method of precipitation evidently carries down not only organisms, but all the material present in particulate form. Inevitably, it does not distinguish between the nitrogen of living organisms and that of detritus. This is unfortunate, but it must be kept in mind that the results of the analysis represent simply the nitrogen present in the particulate matter in a measured volume of water.

Results.

So far five deep stations have been investigated, the samples from all of them having been secured by the research vessel "Atlantis" of the Woods Hole Oceanographic Institution. The data from only one of these have so far been published (v. Brand, 1937). The stations represent different bodies of water: nos. 2639 and 2893, the Sargasso Sea; no. 2896, the Gulf Stream; no. 2894, slope water; and station 2809 the Caribbean Sea (Bartlett Deep). The nitrogen found in the particulate matter is shown in Table 1. It is evident that the greatest variations occur in the upper 400 metres. This is equally true whether comparison is made vertically at a single station or horizontally at different stations. The extreme values are 0·9 and 18 γ of nitrogen per litre ($1\gamma = \cdot001$ mg.). Since 400 metres is generally recognized as about the limit of depth at which plant life is possible, it seems reasonable to assume that the differences found are due to differences in biological activity occurring there. Nevertheless, since a certain amount of detritus was probably present in all samples, it is impossible to attribute these differences solely to the varying amounts of organisms present. It is quite probable that a study of the seasonal variations at these stations would reveal still greater differences. Pronounced

Table 1.

Vertical Distribution of Nitrogen in the Particulate Matter.

Station 2639		Station 2893		Station 2894		Station 2896		Station 2809	
35° 08′ N. 66° 30′ W.		35° 30′ N. 67° 17′ W.		39° 06′ N. 70° 16′ W.		40° 15′ N. 65° 38′ W.		19° 06′ N. 80° 06′ W.	
VII/10-11/36		VII/12/37		VII/21/37		VII/29/37		III/1/37	
Depth m.	Nitrogen per l.	Depth m.	Nitrogen per l.	Depth m.	Nitrogen per l.	Depth m.	Nitrogen per l.	Depth m.	Nitrogen per l.
0	8·4	0	4·9	0	9·0	5	11·0	0	18·0
50	5·0	50	6·1	—	—	48	4·7	52	4·6
100	3·4	98	4·9	85	2·6	97	0·9	102	3·3
200	2·3	194	5·1	171	4·0	145	1·6	201	3·3
300	2·0	289	5·4	244	7·5	193	3·3	301	2·9
400	1·4	383	1·6	323	6·5	290	2·9	401	4·0
500	1·4	479	3·1	404	2·7	386	2·2	500	1·4
600	0	575	2·0	485	3·5	579	3·1	—	—
700	0·7	—	—	641	2·8	—	—	733	3·0
800	1·1	764	2·0	845	4·5	773	1·3	—	—
900	0·8	—	—	—	—	—	—	—	—
1000	1·6	1063	1·3	—	—	—	—	977	0·8
1100	0·2	1129	2·9	—	—	—	—	—	—
1200	0·2	—	—	—	—	1161	0·3	—	—
1300	0·3	—	—	1350	5·2	—	—	—	—
1400	1·6	1358	1·7	—	—	—	—	1463	1·5
1600	1·7	1603	2·3	—	—	1549	1·4	—	—
1800	2·9	1839	1·8	1856	3·8	—	—	—	—
2000	1·4	—	—	—	—	1976	1·4	1947	1·1
2250	2·8	2197	1·9	—	—	—	—	—	—
2500	0·5	2634	2·5	—	—	2472	1·3	2430	1·7
2750	0·8	—	—	—	—	2968	2·6	2910	1·3
3000	2·3	3345	1·8	—	—	3464	0·7	3490	2·0
—	—	3900	1·1	—	—	3960	1·5	3987	1·3
4500	0	4467	0·5	—	—	—	—	4484	1·5
4750	0	—	—	—	—	—	—	4980	2·8
—	—	—	—	—	—	—	—	5480	2·1
—	—	—	—	—	—	—	—	5979	3·0
—	—	—	—	—	—	—	—	6477	2·6

variations of the nitrogen bound up in organized matter would certainly be expected if such an investigation were carried out in the more fertile parts of the sea. It might be mentioned in this connexion that in the vicinity of Iceland values for the "particulate nitrogen" ranging from 10 to 73 γ per litre were found in the surface layers (0 to 50 metres) (v. Brand, 1935). According to a personal communication from Dr. E. Steemann Nielsen, who had collected these samples and studied their plankton, they were exceptionally free from detritus. It seems therefore probable that these values represent very nearly, at least, the amount of nitrogen bound in organisms. The fact that the values for particulate nitrogen in the Iceland water are higher than in any other waters so far investigated is in accordance with the

well-known fact that plankton is much more abundant in northern waters than, for example, in the Sargasso Sea.

It is of some interest to compare the values for the upper layers of stations 2639 and 2893, since both these stations are very nearly at the same spot in the Sargasso Sea. Station 2639 was visited in 1936, and station 2893 in 1937. At the former, the particulate nitrogen decreased rapidly and quite regularly down to about 400 metres. At the latter no significant stratification was found in the upper 300 metres, but at 400 metres the nitrogen had dropped abruptly to about the same level as at station 2639. It is interesting to note that in 1936, at an unnumbered station (v. B r a n d 1937) in the slope water, a regular drop in particulate nitrogen, though with higher absolute values, was found similar to that at station 2639. In the corresponding layers of the slope water at station 2894, sampled in 1937, more or less irregular fluctuations were found. All these data are, of course, still too fragmentary to permit definite conclusions. They seem to indicate, however, that in the same parts of the sea noticeable differences in the distribution of the particulate matter occur from year to year. Apparently an investigation on a larger scale and over a longer period is desirable.

In the layers below 400 metres and down to about 4000 metres, the variations in the particulate nitrogen are much less pronounced than in the upper 400 metres. Practically identical amounts, between 1 and 3 γ per litre, were found in most of the deeper strata at stations 2639, 2809, 2893, and 2896. These values are markedly lower than those found in the upper layer. Both facts, the smaller degree of variation and the smaller absolute values, can be understood by considering the differences in living conditions in the two zones. Only in the upper layers is carbon assimilation possible. Depending upon local and seasonal conditions great differences in both the quantitative amount and qualitative composition of the nannoplankton may be expected there. In the deeper layers living conditions are in many respects much more uniform, resulting in relatively uniform nitrogen values. That these are low can be explained on the assumption that, with the possible exception of certain bacteria, no autotrophic organisms are present. Since K r o g h (1934) has demonstrated that the dissolved organic nitrogen, which occurs in relatively large amounts in all layers of the sea, cannot be used to any noticeable degree by organisms, it appears that ultimately these must depend for their food upon other organisms dying in the surface layers and sinking downwards. Although of course the amount of such food substance coming down may vary widely, according to local and seasonal conditions, it can reasonably be expected that in the enormous deep sea spaces this turnover, passing through a series of stages of unknown duration, may eventually reach an equilibrium. Since the truly productive layers of the surface are very thin, in comparison with the physiologically unproductive space beneath, it is only natural that this equilibrium should result in small amounts of particulate matter in the latter zone.

A comparison of the data from below 4000 metres at stations 2639, 2893, and 2809 reveals a curious situation. In the two former, the Sargasso Sea stations, the lowest values of the whole water column occur in the deepest levels. In the samples taken from the Bartlett Deep, on the other hand, higher nitrogen values were found between 5000 and 6500 metres than between 1000 and 5000 metres (2 to 3 γ and 1 to 2 γ per litre, respectively). This difference may perhaps be explained on the assumption that in the relatively small and isolated Bartlett Deep the conditions for the accumulation of particulate matter, which possibly contains only a small percentage of living organisms, are more suitable than in the open sea. Other chemical analyses of samples from the Bartlett Deep (Rakestraw & Smith, 1937) have also shown the same kind of irregularity in the bottom layers, which may be due to very slow renewal of water here.

So far, the deeper layers of station 2894 (slope water) have not been mentioned. The particulate nitrogen here is distinctly higher than in the Sargasso Sea and the Caribbean, varying between 3 and 5 γ per litre. The reason for this peculiar behaviour is not clear. It may possibly be the result of a higher plankton content of the upper layers, although such a quantitative difference is not clearly indicated by the figures at hand. However, in the previous year the upper 300 metres of slope water yielded values about twice as high as those found in the Sargasso Sea. It must be kept in mind that changes occurring in the upper layers may be relatively rapid and will not necessarily be reflected in the corresponding deeper strata. It is also possible that the distribution of the particulate matter in the deeper layers is not only governed by the amount of dead matter sinking down from immediately above, but is also dependent upon organic matter which originated at some distant point and was carried in by the deeper currents. In other words, hydrographic factors will very likely prove important in the distribution of particulate nitrogen.

In addition to the deep stations, four others, in the shallower waters of the Gulf of Maine, have been investigated. Since the data for those have already been published (v. Brand, 1937), it will be sufficient to mention here only their chief characteristics. The nitrogen values were decidedly higher than in the open sea, from 10 to 34 γ per litre. The greatest amount was present in the upper 40 metres. Below this depth the values were fairly constant, between 10 and 17 γ per litre. A curious fact, as yet not entirely explained, was the observation that at all three of the stations which were deeper than 40 metres the lowest values occurred at intermediate depths, larger amounts being present in the deepest strata.

Discussion.

The nitrogen determined obviously belongs to nannoplankton organisms and organic detritus. Although it would be highly desirable to differentiate between these two factors, the only hope of doing so, even approximately, lies in the combination of chemical determinations

and actual counts of the organisms present. In those rare cases in which one form is highly predominant, an effort might be made to culture it and then determine the nitrogen in a counted sample of pure organisms. A few determinations on pure cultures of diatoms (v. B r a n d, 1935) have shown that the nitrogen method is altogether suitable for this purpose, especially in cases in which the quantity of organisms available is too small for ordinary analytical methods.

The nitrogen determination itself, if handled properly and critically, yields values accurate enough to allow an attack on many problems heretofore considered inaccessible. So far only the very first steps have been taken, as this review has shown. Some of the more easily approachable problems may be mentioned briefly. It would be of great interest, for example, to extend the above studies to different seas and different seasons. The analyses reported for the waters near Iceland, in the Sargasso Sea, and in the Gulf of Maine already indicate that in different types of water different amounts of particulate matter occur. This might, of course, be anticipated from the known data for nannoplankton distribution. However, it would seem that the direct determination of the nitrogen in the particulate matter would corroborate the plankton counts and increase their significance considerably, in so far as the question of circulation of organic matter is concerned.

It is also possible that a more intensive study of the particulate matter would throw light on some hitherto unexplained peculiarities in the distribution of macroplankton in the deep sea. For example, L e a v i t t (1935) found that a minimum of macroplankton occurs in the Western Atlantic at a depth of about 1200 metres. It seems suggestive that at two of the three stations at which samples were obtained from these depths, a distinct minimum of particulate nitrogen was found. It is possible, though scarcely yet proven, that for some reason a minimum supply of food exists in this region, accounting for the scarcity of larger forms.

It may also be possible to study the nutrition of macroplankton organisms by means of this method. It should not be difficult to correlate the particulate nitrogen in a given mass of water with the number of macroplankton individuals, say copepods, and in that way perhaps clarify, to some extent, the food requirements of larger forms.

Finally, it might be possible to decide whether peculiarities in the distribution of particulate matter in the region of the oxygen minimum have any fundamental significance in connexion with this problem.

Summary.

Methods for the determination of the nitrogen in the particulate matter of the sea are reviewed, and the results obtained from such analyses are discussed.

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Über die Anwendung von Netzfängen bei quantitativen Phytoplanktonuntersuchungen.

Von

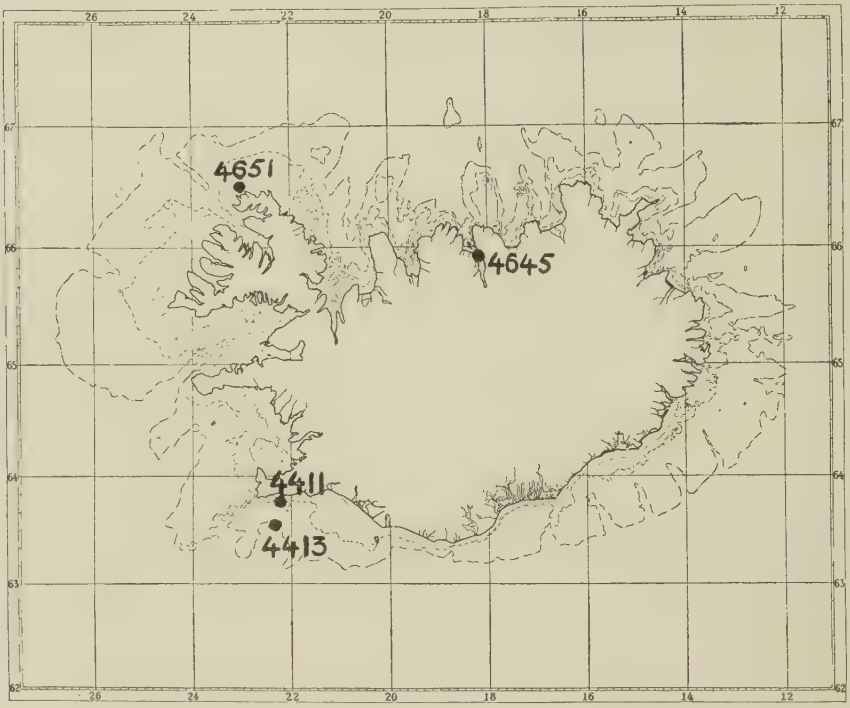
E. Steemann Nielsen.

NETZFÄNGE werden immer noch von einer grossen Anzahl von Planktonforschern benutzt, um die Phytoplanktonmenge zu bestimmen. Dass man nicht alles Phytoplankton hierbei erfasst, darüber sind sich wohl alle klar. Man muss aber annehmen, dass diese Forscher glauben, dass die Netzfänge jedenfalls repräsentative Werte für die Phytoplanktonmenge geben. Dass dies jedoch eine sehr gefährliche Arbeitshypothese ist, soll im folgenden dargestellt werden.

Die Maschen der feinsten Seidengaze haben einen Diameter von rund 50 μ. Organismen, die einen kleineren Diameter haben, können durch die Maschen schlüpfen, wenn sie nicht wie die meisten Arten der Diatoméengattung *Chaetoceros* so lange Hörner haben, dass sie doch von der Seidengaze zurückgehalten werden. Wenn das Verhältnis zwischen grossen und kleinen Arten im Meere immer dasselbe wäre, wäre es möglich, nur die grösseren Arten in Betracht zu ziehen. Dasselbe wäre auch der Fall, wenn die Stoffmasse der kleinen Arten im Verhältnis zu der der grossen Arten minimal wäre. Dies ist jedoch in keiner Weise der Fall. Vor allem auf dem offenen Ozean, aber fast immer auch in Küstengewässern geht die Hauptmasse des Phytoplanktons durch die Maschen des Netzes. Es ist meistens nur ein ganz kümmerlicher Teil, der vom Netze erfasst wird.

Im folgenden sollen einige Phytoplanktonzählungen, die teils durch Netzfänge, teils durch Sedimentation von Wasserproben gewonnen sind, verglichen werden.

Auf der Fahrt der "Dana" an der Nordküste Islands im August 1933 wurden teils Wasserproben gesammelt, deren Phytoplanktongehalt vom Verfasser mittels des umgekehrten Mikroskops von Utermöhl gezählt wurde, Steemann Nielsen 1935; teils wurden gleichzeitig von dem isländischen Planktonforscher Dr. F. Gudmundsson, der die Fahrt mitmachte, 50 l. Oberflächenwasser geschöpft, die durch ein Netz von feinster Seidengaze filtriert wurden. Die Zählresultate sind bei Gudmundsson, 1937, publiziert.



Planktonstationen bei Island. Die Tiefenkurven sind für 200, 100 und 50 m. angegeben.

In den Tabellen 1 und 2 sind die Zählresultate des Oberflächenwassers auf zwei Stationen, wo gleichzeitig Proben von Gudmundsson und Steemann Nielsen geschöpft wurden, verglichen. Der Gehalt der Planktonten ist per 50 l. angegeben.

Diese Tabellen zeigen sehr deutlich, dass nur sehr wenige Phytoplanktonten quantitativ vom Netz erfasst werden. Dies ist der Fall bei den Ceratien — s. Tabelle 2 — und den *Chaetoceros*-Zellen von der Probe aus dem Eyafjord, Tabelle 1; es handelte sich hier um Arten mit sperrigen Hörnern. Dagegen sind die *Chaetoceros*-Zellen der Station 4651 fast garnicht vom Netze erbeutet worden. Es handelte sich hier vor allem um die kleine nicht koloniebildende Art *Chaetoceros simplex.*

Ganz kleine Arten, wie z. B. sämtliche Coccolithophoriden und nackte Flagellaten gehen vollständig durch die Maschen. Aber auch die Hauptmasse der etwas grösseren Arten, die man zum "Mikroplankton" rechnet, werden nur in ganz geringem Masse vom Netz erfasst. Von *Dinophysis (D. norvegica)* wurden vom Netz nur 4 % gefangen, Tabelle 2. Von den Arten der Gattung *Peridinium* wurden auf St. 4645 ca. 0·05 %, auf St. 4651 ca. 0·2 % vom Netz gefangen. Es handelte sich vor allem um die Art *P. triquetrum,* deren Diameter in diesen Proben ungefähr 20—25 μ. war. Von der grossen Diatomée

Tabelle 1.

Plankton per 50 l. Oberflächenwasser, Eyafjord, 65°55′N., 18°12′W., 6. VIII. 1933. St. 4645 (St. N.) = St. 2 (Gudm.)

	Gudm.	St. N.
Peridineen	860	1,300,000
Diatomeen	29,617	23,655,000
Coccolithophoriden		400,000
Flagellaten, nackte		10,000,000
Tintinniden	160	30,000
Infusorien, andere		30,000
Wichtigere Arten:		
Peridinium, alle	140	255,000
Sceletonema costatum	21,000	22,000,000
Rhizosolenia	600	
Chaetoceros, alle	8,000	5,000
Nitzschia delicatissima		800,000

Tabelle 2.

Plankton per 50 l. Oberflächenwasser, 66°30′N., 22°00′W., 7. VIII. 1933. St. 4651 (St. N.) = St. 7 (Gudm.)

	Gudm.	St. N.
Peridineen	39,920	2,810,000
Diatomeen	12,060	2,015,000
Coccolithophoriden		2,810,000
Flagellaten, nackte		18,240,000
Tintinniden	12,000	20,000
Infusorien, andere		15,000
Wichtigere Arten:		
Ceratium, alle	37,680	60,000
Peridinium, alle	2,000	905,000
Dinophysis (norvegica)	600	15,000
Rhizosolenia (semispina)	8,100	45,000
Chaetoceros, alle	380	1,200,000
Leptocylindrus minimus		ca. 700,000
Distephanus speculum		35,000

Rhizosolenia semispina wurden auf St. 4651 ca. 17 % gefangen. Kein einziges Exemplar der grossen Silicoflagellat *Distephanus speculum* wurde auf St. 4651 vom Netz erbeutet, obwohl 35,000 in den 50 l. vorhanden waren.

Das Verhalten von *Distephanus speculum* ist sehr interessant. Die Art variiert in der Weise, dass in einem Gebiet die Hauptmasse der Exemplare grösser alt 50 μ. ist und demnach vom Netz gefangen wird, während in anderen Gebieten sämtliche Exemplare unter 50 μ. sind und demnach nur ganz zufällig vom Netz erbeutet werden.

Ein Beispiel, das besonders deutlich zeigt, welche falschen Werte Netzproben liefern können, geben ferner die Tabellen 3 und 4. Hier sind die Phytoplanktonwerte von zwei Stationen an der Südküste Islands angegeben, teils der Gehalt in 1/100 der Nansenfänge (Seide 25) aus 25—0 m., teils der Gehalt per l. nach den Wasserproben, die nach

Tabelle 3.

Planktongehalt nach Netzprobe (25—0 m.) und Sedimentierungsproben (0, 10 und 25 m.) der St. 4411, 63°49′N., 22°11′W., 28. VI. 1932. Ca. 1000 l. Wasser sind vom Netz filtriert.

	Gehalt in 1/100 der Netzprobe	Gehalt per l. nach Netzpr.	Gehalt per l. nach Sedimpr.
Peridineen	8,396	840	32,800
Diatomeen	411,000	41,000	1,400,000
Coccolithophoriden			364,000
Flagellaten, nackte			157,000
Tintinniden	4,744	474	1,630
Infusorien, andere			2,670
Wichtigere Arten:			
Ceratium longipes	1,044	104	130
Peridinium, alle	7,004	700	16,800
Dinophysis	348	35	130
Leptocylindrus minimus			853,000
Sceletonema costatum	464	46	270
Rhizosolenia delicatula	1,160	116	470
— *semispina (+alata, styliformis)*	1,846	185	600
Chaetoceros, alle	343,000	34,000	27,000
Asterionella japonica	696	70	700
Nitzschia seriata	3,712	371	1,600
— *delicatissima*	59,160	5,900	497,000
Acanthostomella norvegica			400
Helicostomella subulata	116	12	200
Parafavella dentata	2,552	255	300
Ptychocylis urnula	1,384	138	100
Tintinnopsis karajakensis	692	70	600

dem Utermöhl'schen Verfahren bearbeitet wurden. Es wurden die mittleren Werte aus 0, 10 und 25 m. benutzt. Da schliesslich die Menge der sehr grossen Arten *Ceratium longipes, Peridinium depressum* und *Ptychocylis urnula*, die völlig vom Netz gefangen werden, zeigte, dass ungefähr 1000 l. Wasser auf jeder Station vom Netze filtriert ist, sind hiernach die Werte per l. nach den Netzfängen berechnet worden. Beide Stationen liegen innerhalb der 300 m. Kurve, St. 4411 ganz an der Küste, St. 4413 ungefähr 15 Seemeilen weiter draussen.

Nach den Sedimentierungsproben sind beide Stationen sehr reich an Phytoplankton. Die Zusammensetzung der Arten ist jedoch teilweise verschieden. Nach den Netzproben zu urteilen, ist aber St. 4411 sehr reich an Phytoplankton, St. 4413 dagegen ausserordentlich arm.

Nicht einmal die Tintinniden, die man auf keinen Fall als "Nannoplanktonten" betrachten kann, sind auf St. 4413 vom Netze auch nur annähernd quantitativ gefangen. Nur ungefähr 0·03 % sind vom Netz erfasst, während auf St. 4411 dagegen 30 % der Tintinniden vom Netz gefangen wurden. Auf St. 4413 ist der Fangverlust bei den Tintinniden 1000 Mal so gross wie auf der St. 4411. Betrachtet man nur eine einzelne Tintinnidenart, *Parafavella dentata*, ist auf St. 4413 0·12 %

Tabelle 4.

Planktongehalt nach Netzprobe (25—0 m.) und Sedimentierungsproben (0, 10 und 25 m.) der St. 4413, 63°34′N., 22°25′W., 28. VI. 1932. Ca. 1000 l. Wasser sind vom Netz filtriert.

	Gehalt in 1/100 der Netzprobe	Gehalt per l. nach Netzpr.	Gehalt per l. nach Sedimpr.
Peridineen	485	49	37,200
Diatomeen	15	2	351,000
Coccolithophoriden			915,000
Flagellaten, nackte			233,000
Tintinniden	5	0·5	1,500
Infusorien, andere			28,000
Wichtigere Arten:			
Ceratium longipes	65	7	
Peridinium, alle	405	41	267
Dinophysis	5	0·5	67
Minuscula bipes			3,530
Gymnodinien			33,300
Leptocylindrus minimus			244,000
Rhizosolenia delicatula			2,200
Thalassiosira gravida			470
— *sp.*, klein			6,100
Chaetoceros sp., einzellig			40,600
Corethron criophilum			530
Eucampia zoodiacus f. oceanica			3,800
Nitzschia delicatissima			35,000
Acanthostomella norvegica			1,100
Parafavella dentata	5	0·5	400

vom Netz erfasst, auf St. 4411 dagegen 82 %. Der Fangverlust ist demnach auf der St. 4413 ca. 700 Mal so gross wie auf St. 4411.

Der ausserordentlich grosse Unterschied bei dem Fangverlust von *Parafavella dentata* auf den zwei Stationen muss vor allem in der verschiedenen Grösse der Exemplare liegen. Leider existieren die Wasserproben nicht mehr — die Zählungen wurden schon 1932 vorgenommen. Die Grösse der Exemplare in den Netzfängen besagt nicht allzuviel, da die kleineren Exemplare alle durch das Netz geschlüpft sind. Die Breite von 15 Exemplaren der Art aus dem Netzfange der St. 4411 variierte von 48 bis 55 μ. mit einem Durchschnitt von 52 μ., während 2 Exemplare der St. 4413 die Breite 49 und 50 μ. aufwiesen. Es ist aber anzunehmen, dass die Werte auf der ersten Station repräsentativ sind, während dagegen auf der anderen die Hauptmasse der Art nicht die kritische Grösse erreicht hatte. Nur die ganz wenigen sehr grossen Exemplare sind vom Netz erbeutet worden.

In noch höherem Grade als bei den Tintinniden variiert die Grösse der einzelnen Arten bei den Diatoméen. *Thalassiosira gravida*, *Eucampia zoodiacus* und *Corethron criophilum*, die nach den Sedimentierungsproben der St. 4413 in garnicht unbeträchtlicher Menge vorhanden waren, aber vom Netz überhaupt nicht erbeutet wurden, variieren in einem solchen Grade, dass sie auf anderen Stationen völlig

vom Netz gefangen werden. Kein Planktonforscher würde diese Arten zum "Nannoplankton" rechnen. Dies zeigt, dass selbst typische "Mikroplanktonorganismen" auf einigen Stationen völlig durch die Maschen des Netzes gehen. Nur ganz wenige Phytoplanktonarten sind immer so gross, dass sie vollständig vom Netz gefangen werden.

Nicht allein die variierende Grösse der Planktonten auf den verschiedenen Stationen macht es unmöglich, zwei Netzproben quantitativ mit einander zu vergleichen. Der relativ gute Fang von verschiedenen kleineren Arten auf St. 4411 ist ohne Zweifel durch die grosse Menge der *Chaetoceros*-Kolonien bedingt. Diese haben sozusagen einen Filter gebildet, in welchem viele kleinere Phytoplanktonten wie z. B. *Nitzschia delicatissima* gefangen sind.

Ich glaube, dies genügt um zu zeigen, dass Netzfänge weder absolute noch relative Werte der Phytoplanktonmenge geben. Der historische Gang der Planktonforschung trägt ohne Zweifel dazu bei, dass das Netz noch bei quantitativen Phytoplanktonuntersuchungen benutzt wird. Es sind ganz künstlich zwei Phytoplanktongruppen geschaffen worden: das "Mikroplankton" und das "Nannoplankton". Bei quantitativen Planktonuntersuchungen, die eine Bestimmung der Produzenten als Ziel haben, muss man aber alle wichtigeren Organismen, die für die Ernährung der Tiere von Bedeutung sind, mit in Betracht ziehen. Wenn man die Nahrungsquellen der Menschen der verschiedenen Länder untersuchen will, muss man z. B. sowohl die animalischen wie auch die vegetabilischen Nahrungsmittel berücksichtigen. Würde man sich z. B. nur auf die animalischen Nahrungsmittel beschränken, wäre es ganz unverständlich, dass sich in China eine grosse Menschenmenge befindet, während dagegen die Bevölkerung in Grönland nicht zu erklären wäre, wenn nur die vegetabilischen Nahrungsmittel in Betracht kämen.

Den Phytoplanktongehalt im Meere mit einem Netz aus Seidengaze zu bestimmen, ist zu vergleichen mit einer Methode, bei der man versucht, den Fischgehalt zu bestimmen unter Benutzung eines Netzes, dessen Maschen einen Diameter von, sagen wir, 0·5 m. hätten. In einem Gewässer wie z. B. an der Küste Westgrönlands würde man eine relativ grosse Fischmenge finden — es gibt hier die grossen Haie *Somniosus microcephalus.* In einem Gewässer wie z. B. dem Kattegat würde man dagegen bei dieser Methode keinen einzigen Fisch fangen. Ich glaube nicht, dass ein einziger Fischereibiologe diese Methode benutzen würde. In der Planktonforschung wird aber eine ähnliche Methode noch verwendet.

Wenn bei den Fischen immer das Verhältnis zwischen der Anzahl der sehr grossen Fische und dem ganzen Fischbestand immer gleich wäre, könnte man die obenerwähnte Methode sehr gut benutzen. Wäre auch das Verhältnis zwischen den sehr grossen Phytoplanktonten und dem ganzen Phytoplanktongehalt immer gleich, würde man auch mit Erfolg das Netz benutzen können. Nun zeigen aber die Fänge der zwei Stationen 4411 und 4413, dass dies nicht einmal hier der Fall ist, obwohl der Abstand zwischen den Stationen nur 15 Seemeilen beträgt.

Es gibt nicht "Mikroplankton" und "Nannoplankton", es gibt nur Phytoplankton. Die Grösse der Planktonten variiert aber von ganz kleinen bis zu ganz grossen Arten. Im Netze werden nur die ganz grossen Arten gefangen und solche, die wie *Chaetoceros* lange Hörner haben. Wenn letztere im Plankton reichlich vorhanden sind, wird auch ein kleiner Teil von verschiedenen winzigen Arten im Netze zurückgehalten. Wenn in einer Netzprobe nur wenig Phytoplankton vorhanden ist, kann die Ursache darin liegen, dass das Phytoplankton im Meere wirklich arm ist; die Ursache kann aber auch die sein, dass die Grösse und Form der Organismen von einer solchen Beschaffenheit ist, dass sie nicht vom Netz zurückgehalten werden. Die Hypothese, die von vielen Planktonforschern stillschweigend angenommen wird, dass das Netzplankton repräsentative Werte leistet, muss abgelehnt werden.

Die Netzmethode wird nicht wesentlich verbessert, wenn man, wie Gudmundsson, 1937, eine bestimmte Wassermenge durch ein Netz filtriert oder, wie Harvey, 1934, die Wassermenge, die durch das Netz geht, bestimmt. Ebensowenig bedeutet das Sieb aus Bronzegaze, das Hentschel, 1936, benutzt, eine wirkliche Verbesserung, da die Maschen der Bronzegaze von derselben Grössenordnung wie die Maschen der feinsten Seidengaze sind. Das Unsicherheitsmoment, das bei gewöhnlichen Netzfängen vorhanden ist, weil man nicht weiss, wieviel Wasser vom Netz filtriert wird, ist im Verhältnis zu dem anderen Unsicherheitsmoment von ganz untergeordneter Bedeutung, obwohl es an und für sich sehr gross ist.

Bei quantitativen Phytoplanktonarbeiten, die ein Mass der Produktivität des Meeres geben sollen, muss eine Methode wie die von Utermöhl benutzt werden. Hierbei werden sowohl die kleinen wie auch die grossen Arten quantitativ erfasst. Grosse Arten, die sehr spärlich in einem Gebiet vorhanden sind, werden meistens vom Netz erfasst, dagegen natürlich nur zufällig bei einer Methode wie der von Utermöhl. Bei Produktionsuntersuchungen sind aber seltene Arten ganz ohne Interesse. In Gebieten, wo diese Arten bei der Produktion von Bedeutung sind, werden sie auch bei der Methode von Utermöhl erfasst. Auf St. 4645 (Tabelle 1) wurden die grossen *Rhizosolenia*zellen nicht nach Utermöhls Methode erfasst, dagegen in dem Netzfange. Die Menge ist aber auch ganz unbedeutend, nach dem Netzfange 10 per l. Auf der Station 4651 (Tabelle 2) war *Rhizosolenia* dagegen von Bedeutung — 900 per l. —, und hier kommt die Menge dann auch in der Sedimentierungsprobe sehr klar zum Ausdruck. Dasselbe ist der Fall bei *Ceratium longipes* auf den Stationen 4413 und 4411 (Tabelle 4 und 3). Auf der ersten, wo die Art nur in der Menge von 7 per l. vorhanden war, wurde sie nach den Sedimentierungsproben nicht festgestellt. Auf der anderen Station, wo die Menge 15 Mal so gross war, kommt sie dagegen in den Sedimentierungsproben zum Ausdruck.

Es fragt sich nun, ob das Netz bei Phytoplanktonuntersuchungen ganz und gar abgelehnt werden muss. Dies ist natürlich nicht der Fall.

Es gibt ja auch andere Probleme in der Phytoplanktonforschung als gerade die Produktivität. Untersuchungen über die geographische Verbreitung der verschiedenen grossen Phytoplanktonten können erwähnt werden. Eine quantitative Bearbeitung ist hierbei oft zweckmässig, aber naturgemäss nur bei Gruppen wie z. B. den Ceratien, die auch wirklich quantitativ vom Netz erfasst werden.

Von mehreren Seiten, z. B. von Hentschel, 1936, ist betont worden, dass man in der Planktonforschung eine sehr einfache Methode erstreben muss, die sowohl über das Phytoplankton wie auch über das Zooplankton Aufschlüsse gibt. Als eine solche gibt er die obenerwähnte Methode an, bei der ein bestimmtes Volumen Oberflächenwasser durch ein Sieb aus Phosphorbronzegaze filtriert wird. Wie schon erwähnt, führt diese Methode nach meiner Meinung leicht zu ganz falschen Vorstellungen über das Phytoplankton. Dasselbe ist auch bei dem Zooplankton der Fall, indem das Zooplankton in der Oberflächenschicht sehr oft nicht repräsentativ für die ganze Wasserschicht ist. So zeigte z. B. die Untersuchung von Steemann Nielsen, 1935 a, im Faxafloigebiet bei Island, dass der Copepodengehalt auf einer Station bei Keflavig, Tabelle 4, von der Oberfläche bis zum Boden der gleiche war — er wurden Proben aus 0, 10 und 25 m. Tiefe genommen —, während es zur selben Zeit auf einer anderen Station im Hvalfjord, Tabelle 5, in 10 m. Tiefe 10 Mal und in 25 m. Tiefe sogar 100 Mal so gross war wie in der Oberflächenschicht. Es wäre nicht möglich, diese zwei Stationen auf ihren Gehalt an Copepoden zu vergleichen, wenn nur Oberflächenfänge gemacht worden wären.

Es ist nach meiner Meinung wertvoller, wenige Untersuchungen zu machen, die aber den Forderungen an Exaktheit so weit wie möglich entsprechen als extensive Untersuchungen zu machen, bei denen dies nicht der Fall ist. Es ist natürlich von ausserordentlicher Bedeutung, gleichzeitige Untersuchungen über das Phytoplankton und Zooplankton anzustellen; nur in dieser Weise ist es möglich, den Stoffumsatz im Meere kennen zu lernen. Dies erfordert jedoch nicht, dass dieselbe Methode bei der Gewinnung von Phyto- und Zooplankton zu benutzen ist. Der grössere Zeitaufwand beim Einsammeln und bei der Bearbeitung, wenn jede Planktonart nach ihrer Methode behandelt wird, wird sich schon lohnen.

Summary.

The paper shows that nets yield samples which are neither definite nor relative values of phytoplankton quantities. Studying two stations, both rich in phytoplankton, the net samples of one may be rich in plankton while the other one contains but small quantities. The estimate of quantity is not improved through knowledge of the volumes of water filtered by the net. The number of species always quantitatively retained by nets is small, but the relationship of such species to total quantity of phytoplankton being variable, it is considered inadvisable to employ nets in investigating conditions of production of phytoplankton in the sea.

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Der van Veen-Bodengreifer.
Vergleichsversuche über die Leistungsfähigkeit des van Veen- und des Petersen-Bodengreifers.[1])

Von

H. M. Thamdrup,
Skallinglaboratorium, Esbjerg.

ALS ich im Jahre 1934 die zoologische Station in den Helder, Holland, besuchte, zeigte der Stationsleiter, Direktor Dr. J. Verwey, mir einen Bodengreifer, den Dr. J. van Veen vom holländischen Wasserbauamt (Waterstaat) konstruiert hat.

Ursprünglich war der Bodengreifer hauptsächlich für technische Zwecke berechnet; hierüber hat Dr. van Veen eine Mitteilung herausgegeben, gleichzeitig mit einer Abbildung des Apparates (1933). Bei Dr. Verweys Untersuchungen zeigte es sich aber, dass der Bodengreifer auch vorzüglich zu marinbiologischen Studien geeignet sei, und da das Skallinglaboratorium besonderes Interesse für einen Bodengreifer dieser Art hatte, überliess mir der "Waterstaat" gütigst Zeichnungen und Kopierungsgenehmigung. Ich bin den beiden genannten Herren für dieses Wohlwollen Dank schuldig.

Im Sommer 1937 (Mai—Juni) haben wir vom Skallinglaboratorium aus den Apparat in dem dänischen Wattenmeer ausprobiert. Wir haben ihn zu Bonitierungsuntersuchungen angewandt, und ich habe gleichzeitig mit Hilfe des Herrn cand. mag. B. Thomsen die Gelegenheit benutzt, Vergleiche mit einem gewöhnlichen Petersen-Bodengreifer anzustellen. Petersen-Bodengreifer habe ich sowohl vom Zoophysiologischen Laboratorium (Professor A. Krogh) wie vom Marinbiologischen Laboratorium (Dr. Å. V. Tåning) geliehen. Ich bitte hier die beiden Herren, meinen Dank dafür entgegennehmen zu wollen.

Da der van Veen-Bodengreifer — wie man ihn passend nennen kann — sich bei diesen Vergleichsversuchen, die, so weit mir bekannt, nicht früher angestellt sind, in mehreren Punkten einem gewöhnlichen Petersen-Bodengreifer besonders überlegen erwies, schlug ich Herrn Dr. Verwey vor, die bisher erzielten Ergebnisse interessierten Marinbiologen vorzulegen; da aber Dr. Verwey selbst nicht meinte,

[1]) Nach einem Vortrag gehalten am 30. Kongres der Intern. Meeresforschung in Kopenhagen 1937.

entsprechende Vergleichungsgrundlagen zur Verfügung zu haben, forderte er mich auf, meine Ergebnisse zu veröffentlichen.

Die Konstruktion des Bodengreifers geht am besten aus den beigefügten Abbildungen hervor; sein charakteristisches Gepräge liegt in der Verschlussvorrichtung, die mittels zweier sehr langer Hebel funktioniert. Wenn der Apparat ins Wasser versenkt wird, hält man

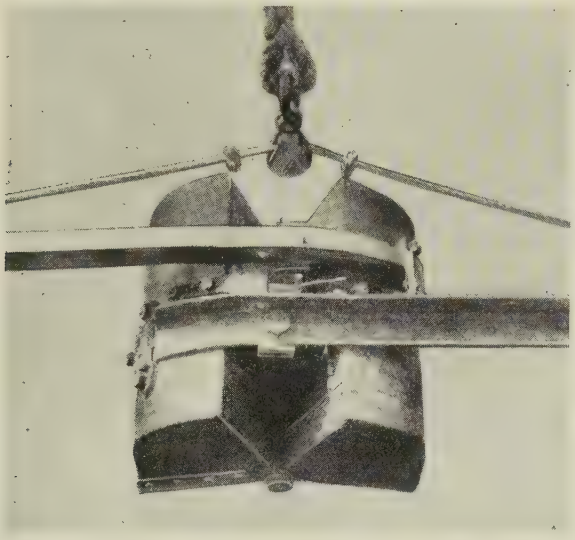

Abb. 1. Der van Veen-Bodengreifer von oben gesehen; zwischen den beiden Armen sieht man die kleine Verschlussanordnung, die den Greifer während des Hinabsenkens offen hält. Will man beim Spülen o. dgl. den Greifer offen halten, kann man eine kleine Stange durch die beiden Löcher stecken, die man in den Armen gleich über der Achse des Greifers sieht.

ihn offen durch einen kleinen Verschlussmechanismus, der leicht ausgelöst wird, wenn der Greifer den Boden berührt. Wenn der Greifer in geschlossenem Zustand nach oben kommt, kann man durch die beiden Ventilklappen Proben von der Oberfläche entnehmen (z. B. für Untersuchungen über Brutstadien verschiedener Bodentiere), oder auch die Proben auf ganz gewöhnliche Weise behandeln.

Zur Illustration der Leistungsfähigkeit des van Veen-Bodengreifers im Vergleich mit dem gewöhnlichen Petersen Typus, besonders auf hartem Sandboden u. dgl., ist in den beigefügten Tabellen eine Übersicht gegeben über Proben aus dem Wattenmeer sowie über Stationen, die die Herren Dr. A a. J. C. J e n s e n und cand. mag. B. T h o m s e n mit dem freundlichen Einverständnis von Herrn Direktor Dr. H. B l e g v a d auf dem "Biologen" im Hornsriff-Gebiet mit unserem Greifer untersucht haben. Ich benutze die Gelegenheit, mich für das zur Verfügung gestellte Material zu bedanken.

Ich will hier nicht auf Einzelheiten eingehen, sondern nur einige der wichtigsten Resultate hervorheben. Im Wattenmeer hat der van Veen-Bodengreifer ($^1/_{10}$ m^2., 45 kg. Leergewicht) durchschnittlich etwa 4·3 l. Material gehoben u. zw. jedes Mal mit etwa 1·5 g. Tieren, während der entsprechende Petersen-Greifer (45 kg.) etwa 1·5 l. Material und 0·53 g. Tiere per $^1/_{10}$ m^2. heraufgeholt hat. Der van Veen-Bodengreifer hat also etwa dreimal so viel Tiere erfasst, was u. a. auf die Tatsache zurückzuführen ist, dass er tief genug geht, um grabende Formen wie *Scoloplos* in grosser Anzahl heraufzuholen.

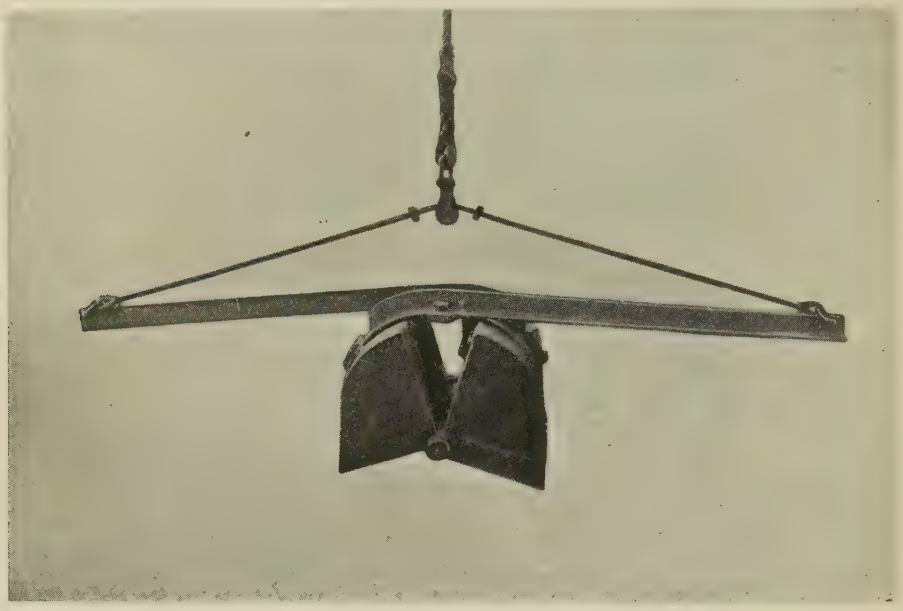

Abb. 2. Der van Veen-Greifer klar zum Gebrauch.

Im Hornsriff-Gebiet sind nur wenige Proben mit beiden Bodengreifern an derselben Stelle gemacht worden; es wird aber dennoch aus den Ergebnissen hervorgehen, dass der van Veen-Greifer dank seines tiefergehenden Arbeitsverfahrens durchschnittlich die grösste Tiermenge per Probe erzielt hat. Hier hat der van Veen-Greifer nämlich Echinocardien mit nach oben gebracht, die der Petersen-Greifer nur ausnahmsweise mitgeführt hat.

Da eine ganze Reihe von Bonitierungsuntersuchungen in Meeresgebieten mit hartem Boden (Sand u. dgl.) mit dem gewöhnlichen Petersen-Greifer bisher, wie schon von Hagmeier u.a. betont, schwer durchführbar gewesen sind, finde ich es auf jetziger Grundlage berechtigt, auf die guten Eigenschaften des van Veen-Greifers aufmerksam zu machen.

Es wird aus dem obenstehenden hervorgehen, dass der van Veen-Greifer im Verhältnis zu seinem Gewicht (45 kg. für $^1/_{10}$ m^2.) auch

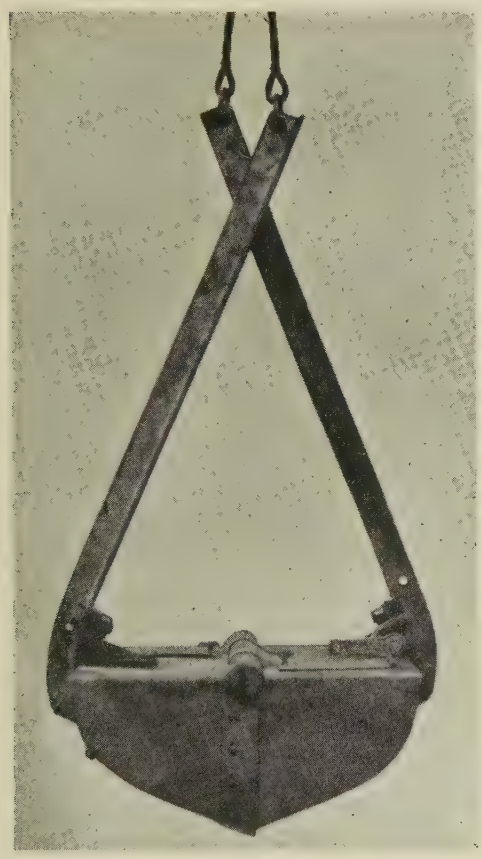

Abb. 3. Der Greifer kommt geschlossen nach oben; rechts am Grunde des Armes sieht man den kleinen Verschlusshebel und an der Oberseite sind die beiden Ventilklappen sichtbar.

auf hartem Sandboden eine bedeutende Leistungsfähigkeit besitzt, und er arbeitet mindestens eben so schnell und zuverlässig wie der Petersen-Greifer. Vergleichsversuche mit einem unbelasteten van Veen- und einem belasteten Petersen-Greifer habe ich nicht vorgenommen; es ist möglich, dass der belastete Petersen-Greifer eben so viel leisten kann. Hagmeier hat ja z. B. gezeigt (1930), dass man mit einem schwer belasteten Petersen-Greifer ($^1/_{10}$ m^2. von 115 kg. Leergewicht) auch auf Sandboden sehr gute Resultate bekommen kann; wie man sieht ist aber eine ganz beträchtliche Belastung des Petersen-Greifers notwendig.

Beim Arbeiten in unruhiger See ist der leichtere van Veen-Greifer jedenfalls, wie es sich schon an Bord des "Biologen" erwies, ohne Zweifel vorzuziehen, und besonders für den Gebrauch in kleineren Fahrzeugen, wie z. B. in dem vom Skallinglaboratorium verwendeten 8 m. langen Motorboot, ist der van Veen-Greifer zu empfehlen.

Für grössere Untersuchungsschiffe wird ein grösserer, vielleicht auch belasteter van Veen-Greifer ($^1/_4$—$^1/_5$ m^2. = der originale, holländische

Apparat) sich sicherlich mit Vorteil verwenden lassen, wenn höchste Leistungsfähigkeit erwünscht ist.

Infolge seiner Konstruktion kann der van Veen-Greifer sich wohl nicht mit dem Knudsen-Bodengreifer (1927) messen was tiefergehende Effektivität anbelangt, er wird aber doch sicher einen Platz auf dem Gebiet der Bonitierungs-Untersuchungen ausfüllen können.

Unser Apparat ist vom Konservator an der Polytechnischen Lehranstalt zu Kopenhagen, Herrn H. J. Nielsen, hergestellt. Konservator Nielsen hat gewisse Verbesserungen am Original vorgenommen; so sind die zwei langen Arme an unserem Apparat abnehmbar (Transport u.ä.) und der Greifer kann mittels einer einfachen Stange offen gehalten werden, wenn man z.B. den Apparat spülen will. Der Bodengreifer — $^1/_{10}$ m^2. — wird vermutlich zu einem Preise von 300—350 dän. Kronen geliefert werden können.

Übersicht über einige Ergebnisse mit dem van Veen-Bodengreifer im dänischen Wattenmeer und Hornsriff-Gebiet im Vergleich mit dem Petersen-Bodengreifer.

I. Stationen im dänischen Wattenmeer, 0·5—4 m. Tiefe:

Stat. A. Hjerting Løb, tongemischter Sand.

van Veen $^1/_{10}$ m.^{2}, 45 kg.			Petersen $^1/_{10}$ m.^{2}, 45 kg.		
Probe No.	Material l.	Tiere g.	Probe No.	Material l.	Tiere g.
1	3·2	1·31	7	2·2	0·45
2	3·8	1·60	8	1·6	0·01
3	3·2	1·15	9	1·3	0·50
	10·2	4·06		5·1	0·96
pro $^1/_{10}$ m.^{2}:	3·4 l.;	1·35 g.	und	1·7 l.;	0·32 g.

Stat. B. Wattkante bei Langli Sand; fester Sand.

van Veen $^1/_{10}$ m.^{2}, 45 kg.			Petersen $^1/_{10}$ m.^{2}, 45 kg.		
No.	l.	g.	No.	l.	g.
13	6·4	2·86	16	2·2	0·02
14	5·3	1·45	17	2·6	0·01
15	3·3	0·20	18	1·3	0·01
	15·0	4·51		6·1	0·04
per $^1/_{10}$ m.^{2}:	5·0 l.;	1·50 g.	und	2·0 l.;	0·01 g.

Stat. C. Wattkante an der Ostküste Skallingens; fester Sand.

van Veen $^1/_{10}$ m.^{2}, 45 kg.			Petersen $^1/_{10}$ m.^{2}, 45 kg.		
No.	l.	g.	No.	l.	g.
19	5·1	5·00	23	1·6	3·20
20	3·2	2·06	24	1·6	0·32
21	5·1	3·45	26	1·6	3·25
	13·4	10·51		4·8	6·77
per $^1/_{10}$ m.^{2}:	4·5 l.;	3·50 g.	und	1·6 l.;	2·25 g.

Stat. D. Ho Bucht, östlich von Ho; Schlickboden mit Sand.

van Veen 1/10 m.², 45 kg.			Petersen 1/10 m.², 45 kg.		
No.	l.	g.	No.	l.	g.
27	4·3	1·30	30	1·6	0·30
28	3·2	0·65	31	1·3	0·35
29	3·2	0·40	—		
	10·7	2·35		2·9	0·65
per 1/10 m.²:	3·6 l.;	0·78 g.	und	1·45 l.;	0·33 g.

Stat. E. Ho Bucht, nördlich von Nyeng; fester Sandboden.

van Veen 1/10 m.², 45 kg.			Petersen 1/10 m.², 45 kg.		
No.	l.	g.	No.	l.	g.
35	4·3	1·10	32	0·6	0·20
36	4·3	1·05	33	1·6	0·25
37	5·1	1·00	34	1·1	0·15
	13·7	3·15		3·3	0·60
per 1/10 m.²:	4·6 l.;	1·05 g.	und	1·1 l.;	0·20 g.

Stat. F. Ho Bucht, westlich von Marbæk, fester Boden.

van Veen 1/10 m.², 45 kg.			Petersen 1/10 m.², 45 kg.		
No.	l.	g.	No.	l.	g.
38	5·1	0·50	41	0·8	0·15
39	4·3	0·55	42	0·9	—
40	4·3	0·30	43	1·6	0·15
	13·7	1·35		3·3	0·30
per 1/10 m.²:	4·6 l.;	0·45 g.	und	1·1 l;	0·10 g.

Im Durchschnitt hat
der van Veen-Bodengreifer, 1/10 m.², 45 kg. : 4·3 l. Material und 1·44 g. Tiere;
der Petersen-Bodengreifer, 1/10 m.², 45 kg. : 1·5 l. Material und 0·53 g. Tiere;
per Probeentnahme im Wattenmeer gegeben.

II. Stationen im Hornsriff-Gebiet 10—30 m. Tiefe (von den Herren Dr. Aa. J. C. Jensen und cand. mag. B. Thomsen untersucht und hier von Herrn Direktor Dr. H. Blegvad zur Verfügung gestellt).

Stat. 5306; tongemischter Sand.

van Veen 1/10 m.², 45 kg.			Petersen 1/10 m.², 41 kg.		
	l.	g.		l.	g.
3 Proben	4·3		3 Proben	1·6	
	3·2			2·2	
	3·2			3·8	
	10·7	3·6		7·6	0·8
pro 1/10 m.²:	3·6 l;	1·2 g.	und	2·5 l;	0·27 g.

	Petersen 2/10 m.², 136 kg.	
	l.	g.
2 Proben	1·0	
	1·0	
	2·0	1·6
pro 1/10 m.²:	0·5 l;	0·40 g.

Stat. 5307; Feiner Sand mit etwas Ton.

van Veen $^1/_{10}$ m.^{2}, 45 kg.	l.	g.
3 Proben	3·2	
	3·2	
	3·8	
	10·2	1·9
per $^1/_{10}$ m.^{2}:	3·4 l;	0·63 g.

Petersen $^1/_{10}$ m.^{2}, 45 kg.	l.	g.
3 Proben	1·1	
	1·1	
	1·6	
	3·8	0·9 g.
und	1·3 l;	0·30 g.

Petersen $^2/_{10}$ m.^{2}, 136 kg.	l.	g.
2 Proben	1·6	
	1·6	
	3·2	0·10 g.
per $^1/_{10}$ m.^{2}:	0·8 l;	0·05 g.

van Veen $^1/_{10}$ m.^{2}, 45 kg.	Liter Material per Probe (Durchschn.)	g. Tiere per Probe (Durchschn.)
Stat. 5306; tongemischter Sand ..	3·5	38·0
„ 5308; grober Sand	2·5	49·2
„ 5309; feiner Sand	2·0	1·5
„ 5310; „ „	3·0	6·6
„ 5311; „ „	5·5	0·1
„ 5312; „ „	3·0	19·6
„ 5313; „ „	2·5	14·9
„ 5314; „ „	3·0	76·5
„ 5315; „ „	4·0	45·5
„ 5316; „ „	3·5	52·4
„ 5317; „ „	2·5	0·7
„ 5318; tongemischter Sand ..	2·5	17·0
	37·5	322·0

Petersen $^2/_{10}$ m.^{2}, 136 kg.	Liter Material per Probe (Durchschn.)	g. Tiere per Probe (Durchschn.)
Stat. 5295; feiner Sand	1·00	0·1
„ 5296; „ „	0·75	1·7
„ 5297; „ „	0·75	1·6
„ 5298; „ „	0·75	0·5
„ 5299; dunkler tongemischter Sand	1·00	4·1
„ 5300; heller tongemischter Sand	1·25	0·7
„ 5301; heller tongemischter Sand	2·00	0·6
„ 5302; feiner Sand	2·00	0·6
„ 5304; „ „	1·00	20·9
„ 5305; tongemischter Sand ..	2·00	1·00
	12·50	31·8

Der van Veen-Bodengreifer (45 kg. $^1/_{10}$ m.^{2}) hat im Durchschnitt von 12 Proben
3·1 l. Material und
26·8 g. Tiere per $^1/_{10}$ m.^{2} gehoben.

Der Petersen-Bodengreifer (136 kg., $^2/_{10}$ m.^{2}) hat im Durchschnitt von 10 Proben
0·63 l. Material und
1·60 g. Tiere per $^1/_{10}$ m.^{2} gehoben.

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A Method for Cutting Sections of Otoliths of Cod and Other Fish.

By

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FOR many years the inspection of cod otoliths has been effected by the very simple process of breaking the otolith approximately across the middle, probably grinding it a little and placing the best piece under water or alcohol and examining it by oblique reflected light (this can be done under the binocular microscope)[1]). With practice the number of annual rings can be determined with fair accuracy by this method; but if the break is unsatisfactory or perhaps results in the complete destruction of the otolith, then a determination is lost. Furthermore, when breaking the otolith, it is difficult to make certain that the section will be just in the middle. When it is not so, in the case of slow-growing cod, there is the risk of overlooking the first winter ring and the determination consequently becomes worthless. Lastly, it is extremely difficult to effect proper comparison of the courses of the annual rings, when one has to deal with a whole series of very irregularly cut otoliths; it is also unsatisfactory to have a large amount of really valuable material lying about as small, half-crumbling pieces.

In my studies of the fluctuations of the year-groups, examination of large numbers of cod otoliths from the Faroes, Iceland, and other waters led me some years ago to prepare cod otoliths in such a way that the shortcomings of the methods hitherto used, as described above, could be avoided to a great extent.

During the last five years we have prepared several thousand cod otoliths by this particular process and since it has proved a great success in saving both time and temper, I give a brief description of it here. The method was demonstrated to members at the Council Meetings in 1934 and 1935.

The basic principle of the method is to fix the otolith one intends to section in such a way that a simple grinding machine can rub it down accurately to the required surface. To do this, the otolith is embedded

[1]) See *inter alia* Bjarni Sæmundsson: On the age and growth of the Cod etc. Medd. Komm. f. Havunders., Ser. Fiskeri, Bd. VII, 3, 1923, p. 6.

in plaster of Paris. For this operation, a block of wood is used, about 2—2½ cm. high and with, say, 5 holes drilled in it; each hole is lined with a metal cylinder (like a hole on a putting green) of a diameter

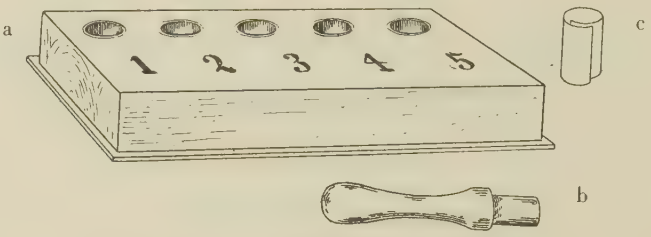

Fig. 1.

of 15—16 mm. Fig. 1 shows such a block of wood (a) lying on a plate of glass, which serves to retain the liquid plaster with which the holes are filled. Each hole is numbered, to facilitate identification of the otolith placed in it. Before the holes are filled, each is lined with paper (c), which helps in the removal of the plaster. This can best be done by means of a suitable wooden plug (b).

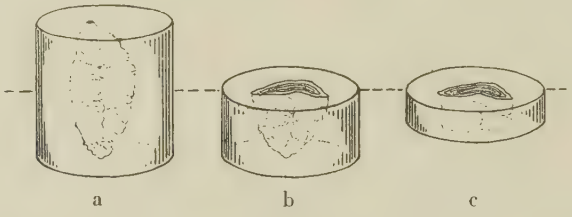

Fig. 2.

The plaster is coloured black by mixing with it a small quantity of black manganese slaked in water and then stirred well into the fluid plaster mixture. The otoliths are lifted with forceps and placed in the soft plaster as soon as this fills the holes, taking care that the otoliths stand vertically with the pointed end downwards (see Fig. 2a). For practical purposes it is best to have 8 of these wooden blocks, so that one can embed 40 otoliths at once.

When the plaster block is half-dry, it is pushed out of the wooden holder and laid in its own small box, which carries the data regarding the fish's length, sex, etc. When the plaster is quite dry and hard, the grinding can begin. For this purpose a simple electric grinding machine is used (Fig. 3)[2]; at one end this is provided with a circular steel plate rotating vertically, on which is fixed, by means of photographic paste, a piece of carborundum paper cut to suit the plate. The

[2]) This can be obtained from Konservator H. J. Nielsen, Polyteknisk Læreanstalt, Copenhagen; price about 300 Kroner according to model desired.

latter rotates at high speed (1,200—1,800 revolutions per minute) close up against a steel table bearing a sliding block. The cylindrical plaster cast containing the otolith is placed on the sliding block and pushed horizontally in against the rotating grinding surface.

The procedure is now quite simple; first of all, so much of the ends of the plaster cast is ground down as will just enable one to see the points of the otolith (Fig. 2a). Then one marks with a pencil on the outside of the plaster block the exact position of the centre of the otolith (a small millimetre-scale can be used for the purpose). The grinding is continued down to this mark (Fig. 2b) and we thus obtain

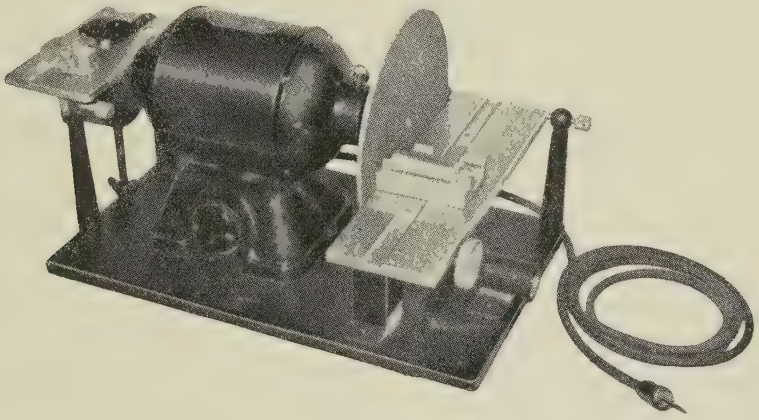

Fig. 3.

a smooth section through the middle of the otolith. A cross is marked on the plaster to indicate that this surface has to be used in counting the rings. So that the plaster block with the otolith should not take up too much space, the block is turned round and a piece of the other end is also ground down (Fig. 2c).

In practice, it is of great advantage to fix a circular piece of coarser carborundum paper on the outer part of the rotating disk, leaving the finer carborundum paper on the inner part; the first and rougher part of the grinding can thus be accomplished more quickly on the outer part, leaving the inner part to do the finer grinding later.

Using this procedure, a technical assistant can prepare at least 150 samples in one day and thus save an extraordinary amount of time. The actual grinding only takes about a moment for each otolith.

To examine the otoliths, the small plaster disk is placed in a Petri dish containing xylol, which soon penetrates the plaster. The black manganese in it provides a black background for the otolith, against which the growth-rings stand out very clearly. The reading of the number of rings is then just a matter of a few seconds, if the source of light is strong. In these sections, we can also readily measure the breadth of the rings, and in general all the peculiarities of the otolith stand out very clearly.

In this method of preparation we lose half the otolith; to obviate this, in the case of specially valuable material, I have had a small circular saw constructed for attachment to the other end of the axle of the motor carrying the grinding plate, as shown in the figure (Fig. 3). A special carrier brings the exact middle of the plaster block containing the otolith against the saw, which cuts through the otolith in a moment. The thickness of the saw is only about one-fifth of a millimetre, but it is of specially hard steel. The teeth get worn down in the course of time but some 20—30 otoliths can, however, be cut with the same blade. A slight grinding of the surfaces after sawing gives two preparations of the same otolith (or 4 from the same fish, if desired).

Trials have also been made with this type of grinding machine to obtain otolith sections thin enough to fix on glass (ca. 0·2—0·3 mm. thick), so as to be transparent and suitable for projection with the lantern, but the thin sections are too fragile to stand the strong vibration of the grinding disk. The ordinary mineralogical grinding machines, with a grinding plate of lead or tin rotating horizontally, on which carborundum powder in water is used, are better suited for the preparation of sections thin enough to be photographed, for example.

Finally, it should be mentioned that the dust from the grinding, which may cause trouble to the breathing organs, can be removed very simply by attaching a "vacuum-cleaner" to the machine. In Fig. 3, below the plate to the right, can be seen the opening of a pipe or tube which can be connected with the cleaner; the pipe runs into a chamber below the steel table and the rapid revolution of the grinding surface drives practically all the dust into this chamber.

This grinding operation can of course be used for the preparation of otolith sections of all fish of which the otoliths are not too small. It can also be used for many other objects, such as corals and the like, where sections are desired for closer study.

For assistance in working out the method and in constructing the grinding machine I desire to express my best thanks to Konservator H. J. Nielsen and Mr. B. Jepsen.

Tuna Tags.

By

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AN announcement of the tuna tagging programme of the California State Fisheries Laboratory, with a description of the tags used, was made in the *Journal du Conseil* in 1936 (Vol. XI, No. 1, pp. 94—97). Despite the fact that nearly 4,000 fish had been tagged by the end of 1936, no recoveries have been made. This fact has gradually raised apprehensions concerning the fate of the tags, and an effort was made to determine possible sources of loss. Early in 1936 a study of this problem was made on a fishing boat and it was discovered that the peculiar methods of handling tuna on the commercial vessels were possibly responsible for the loss of a moderate proportion of recovered tags. Unfortunately, this contingency was not foreseen.

Due to the size of fish and the force with which they strike the deck, it is necessary to protect the wooden decks of a commercial tuna boat from excessive wear. This is done by means of gratings covering the entire afterdeck. When fishing ceases, the tuna between bait tanks and rail are slid forward, often with considerable velocity, to the hatch. By tagging a number of dead fish it was determined experimentally that in this operation a number of tags were damaged or lost. The concave, celluloid disk was apt to catch on the wooden gratings, and when this happened either the disk broke or the entire tag was loosened, tearing out entirely in extreme cases. Between 20 and 30 per cent. of the tags were thus damaged in this experiment. Whereas the tuna are tagged on the right side, the fish on the vessels are slid forward indiscriminately on whichever side happens to be down; therefore the possible theoretical loss of tags from this cause should not exceed 10 or 15 per cent. of recovered fish.

With no returns coming in, this possible source of loss could not be overlooked, and the situation was remedied immediately by reversing

the disk on all fish tagged subsequently, so that the concave side pressed firmly against the pre-operculum. With tags applied in this manner, experiments showed that there was neither loss nor damage to the tags from the above cause. However, this was essentially a make-shift, because experience of other workers in other fisheries has shown that when a tag is pressed firmly against the operculum, there is a pronounced tendency for the tissues to overgrow and thus obscure the tag. Consequently efforts were made to solve this difficulty in a more satisfactory way.

The purpose of the disk is solely to attract attention. Without this spot of colour, the silver straps are inconspicuous. An obvious solution to this problem would be to colour the silver straps and dispense with the disks entirely. Pursuing this idea, 12 sample tags were secured through the courtesy of the Whitehead and Hoag Company, of Newark, New Jersey. Six of these were coloured on the exposed surface with soft enamel, and the remaining six with jeweler's hard enamel. The enamels, applied by the manufacturers, were those commonly used on badges and emblems. These 12 tags were subjected to tests in salt water on a commercial tuna boat, operating off the coasts of Latin America, and later some were tested further in California waters.

Three tags of each type were fastened by means of minute silver nails to the guard rail of a tuna boat on the water-line. In this position they were subjected to turbulent water when the vessel was under way (speed about nine knots) and momentarily to wind and tropical sunshine with each roll of the vessel.

The remaining three tags of each type were fastened within the coaming of a bait tank in such a position that they were covered constantly by gently circulating sea water. Without entering into unnecessary detail, it will suffice to recapitulate the results thus far.

Soft Enamel Tags.

The three tags on the guard rail, exposed to turbulent sea water, lost all trace of colour (enamel) within 23 days. After this interval the metal was bare and clean.

The three tags within the bait tank, exposed to gently circulating sea water, lost all trace of colour by the 54th day. All trace of enamel was gone and the metal was bare and clean.

Hard Enamel Tags.

All tags in both locations withstood the test and at the end of the trip showed neither loss of colour nor any deterioration in the enamel. The test was accordingly extended for a second trip, all tags in this case being exposed to the more rigorous conditions on the guard rail at the water-line. After a total exposure ranging from 106 to 118 days, all tags had withstood the test, showing no signs of wear or change.

The test was again extended, and four of the above six tags were fastened to the keel of a 45-foot patrol boat of the California Division

of Fish and Game. For 103 days they remained there with the boat operating constantly (cruising speed about 16 knots) in local waters. After this interval the tags were removed and inspected with the following results.

In three cases the enamel was entirely intact and showed no signs of wear or abrasion. In the remaining case the enamel was essentially comparable to the above, but in one corner it was chipped and crushed as though by a mechanical blow. Despite this, there were no indications of disintegration of the enamel adjacent to the broken surface, which remained hard and metallic.

An unforeseen result was the darkening of the enamel and a pronounced tarnishing of the silver. This happened in all four tags subjected to the final test and was all the more surprising because no evidence of discolouration of the enamel nor tarnishing of the silver was apparent in any tag after 118 days' exposure on a tuna boat. The most probable explanation of this is to be found in the fact that the patrol boat operates in local waters and is moored in an industrial harbour where hydrogen sulphide is undoubtedly produced. A synopsis of the history of the tags plated with jeweler's hard enamel follows.

Tags 7 and 8 exposed 221 days as follows:—

54 days	Bait tank—gently circulating sea water	
12 days	Bait tank—empty: rain, shade, and tropical sun	
52 days	Guard rail—on water-line	
118 days		No deterioration.
103 days	Keel of patrol boat	Enamel hard and intact but discoloured with silver badly tarnished. Enamel chipped in one corner of tag 7 as though mechanically.

Tag 9 exposed for 118 days as follows:—

54 days	Bait tank—gently circulating sea water	
12 days	Bait tank—empty: rain, shade, and tropical sun	
52 days	Guard rail—on water-line	
118 days		No deterioration.

Tags 10 and 11 exposed for 209 days as follows:—

106 days	Guard rail—on water-line	No deterioration.
103 days	Keel of patrol boat	Enamel hard and intact but discoloured. Silver badly tarnished.

Tag 12 exposed for 106 days as follows:—

106 days	Guard rail—on water-line	No deterioration.

The results of this experiment show conclusively that the soft enamel used herein is entirely unsatisfactory. It is rapidly removed by

exposure to sea water, the rate of removal depending upon the exposure. The hard enamel, on the contrary, is not affected by a seven-months' exposure to sea water under varying conditions. After this time the enamel was entirely intact (disregarding tag 7), hard, and showing no deterioration. However, whereas tags exposed for 106 days in tropical ocean water showed neither tarnishing of the silver nor discolouration of the enamel, the same tags after an additional exposure of 103 days in California waters (and harbours) were badly tarnished with pronounced discolouration of the enamel. In all cases the colour darkened and became less conspicuous. It is suggested that this is due to the reaction of the hydrogen sulphide produced in industrial harbours with both the silver and some constituent of the jeweler's hard enamel. Notwithstanding this, results are sufficiently encouraging to warrant the use of a jeweler's hard enamel as a conveyor of colour on a tuna tag. Unfortunately the cost of such tags is high, and in view of this it seems advisable to extend the experiments and consider other alternatives before adopting this tag. Meanwhile our tagging programme will continue, using the tag previously described with the disk inverted.

A System of Oyster Culture.

By

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Introduction and Description of Breeding Tanks.

THERE is described below a system of oyster culture, depending upon the collection of spat in tanks, which has been successfully employed for a period of years at the Conway Station of the Ministry of Agriculture and Fisheries. Throughout this account the species of oyster referred to is *Ostrea edulis,* the European flat oyster. This description is intended as a basis upon which others attempting the culture of oysters in tanks may work, and throughout, attention is directed towards points of importance in establishing new stations for oyster culture.

The tanks in which the collection of oyster spat is carried out have already been described by Dodgson (1928) and Cole (1936), so that only the shortest possible description will be given here. The two tanks relied upon for the collection of spat are constructed of reinforced concrete, and are straight-sided and rectangular, with a depth of a few inches over six feet. Each tank holds 90,000 gallons. They are terraced on a sloping field with a north-easterly aspect, but are, nevertheless, exposed to the prevailing westerly winds, being sheltered only by a shed six feet high, used to house the tiles which serve as collectors for oyster spat. The upper tank is considerably more exposed than the lower, but also receives more sunshine. The results in the two tanks have not been noticeably different over a period of years. In the selection of a site for tanks designed for oyster breeding it would be advisable to choose one exposed to full sun and sheltered to some extent from cooling winds. In certain places where experimental oyster breeding has been tried the exposure of the tanks has been such that the temperature of the tank water has not reached a level high enough to induce a sufficient number of the stock oysters to spawn. Information on the temperature level which it is necessary to attain is given later.

A large number of experiments have been carried out in shallow tanks, with depths of 3—4 feet, both at Conway and elsewhere, with very slight succes. It may be that the very rapid changes in temperature, etc., in such shallow tanks, are inimical to the development of oyster larvae; or again, there is some reason to believe that the intensity of light in such shallow tanks has a harmful effect on the larvae. Whatever may be the true reason for the failure, it is certain that the use of tanks of a depth less than six feet, or of a capacity much below that of the large tanks at Conway, cannot be recommended. Larger tanks of this depth would, however, be eminently suitable. The shallow tanks at Conway have been tried so often that no doubt remains as to their unsuitability for this work. All attempts to raise oysters in shallow pits such as abound on the east coast oysterages are therefore doomed to failure unless such pits are modified to provide the right depth and volume of water.

The tanks are situated about two miles up river from the mouth of the Conway, but on spring tides the river is tidal for a distance of ten miles from the mouth. The end of the intake pipe lies at the edge of the deep channel in the river bed, so that, by pumping at high water on a spring tide, it is possible to obtain water which has undergone very little contamination with inshore mud banks in its passage up the river. The importance of obtaining off-shore sea water as far as possible will be discussed later, but it may be mentioned here that, in the selection of a site for tanks, it is desirable to choose one adjacent to a deep channel, and on no account should a site be selected where the water entering the intake main would have to traverse any extensive area of inshore banks. The situation of the Ministry's tanks at Lympstone, Devon, built for mussel cleansing, illustrates fully the sort of site which should be avoided. The deep channel of the River Exe is about one mile from the inlet main, on the opposite side of the river, and all water entering the main has first to cross this mile of mud flats, thus ensuring almost the maximum contamination with inshore and littoral organisms. In practice the successes at the Lympstone tanks have been intermittent and on many occasions the rapid growth in the tanks of inshore algae, unsuitable as food for oyster larvae, has prevented any success. At Conway on the other hand, experience during the last few years has shown that the growth of such unsuitable organisms in the tank waters can, with care, be avoided. It is further important from economic considerations to select a site adjacent to a foreshore on which it is known that good growth of oysters can be obtained. The transfer of spat from the tanks to open water can then be effected cheaply and expeditiously.

Concrete tanks with natural, i. e., mud or gravel, floors are unsuitable for oyster culture. Experience at Lympstone with a tank of this type has shown that such natural bottoms rapidly set up unfavourable water conditions in stagnant tanks.

The Preparation of Tanks and Collectors.

The terraced nature of the tanks at Conway makes it possible to fill the lower tank from the upper, and this is our usual practice, the delivery main from the pump entering the top tank. Some days before the tanks are filled for the season, the walls are sprinkled with a strong chlorine solution to free them from algal growths, which may accumulate during the early months of the year when the tanks are used for other purposes. They are then thoroughly hosed down and left for a day or two to disperse any traces of chlorine which may remain.

It has been usual at Conway, for the sake of convenience, to distribute some 1,500 limed tiles, in groups of ten, on the floor of each tank before filling, and to add further tiles on the approach of a good spat settlement. In a commercial operation one would advise the placing of collectors in the less accessible central parts of the tank at the time of filling, further tiles being added round the side at intervals when a good spatfall appears to be imminent. In a tank six feet deep one would recommend placing bundles of collectors not more than two feet apart. Further additions can be made if the spatfall is likely to be very large. One has to aim at catching sufficient spat to give a survival of about 100 oysters per tile in the following spring. In order to do this it is probably necessary to catch initially four or five times this number. The collectors principally used at Conway have been the French curved tiles, shaped like the third of an ordinary field drain pipe, and of the same semi-porous nature. They are coated during the spring with a mixture of freshly hydrated lime, mud, and sand. The mixture in most general use at Conway has been 2 parts sand, 1½ parts lime and 1 part mud, but there is a good deal of variation in both the composition of the ingredients and of the mixtures used in France, where the coating of tiles with lime was first developed. If too much sand is used the coating becomes very hard and it is difficult to detach the spat without damage. If too much lime is used the coating is inclined to crack and flake off prematurely. One should aim at giving the tiles an even coating of a thickness between $^1/_{16}$th and $^1/_8$th of an inch. It is probably better to dip the tiles twice and have two thin coatings, rather than one thicker one. After dipping, the tiles should be exposed to air but protected from rain for at least ten days while the coating matures, i.e., the hydrated lime is converted to carbonate. In France they may be used loose or wired in bundles of twelve, but at Conway the tiles are strung together with trawl twine in groups of ten. In the still waters of tanks wire of all kinds should be avoided, and it is doubtful whether in a commercial operation the extra time and expense of stringing would be justified. At Conway it is often found necessary to cut open the bundles after the spat have settled, in order to remove the attached organisms such as sea-squirts. It is, however, convenient, and indeed necessary, to have a certain number of bundles of tiles tied up, so that they can readily be lifted up for examination.

Collectors other than tiles might be employed with profit. The cost of handling and liming the tiles, stripping off the spat, etc., might be avoided by employing a form of collector or culch which could be distributed broadcast over the beds with the young oysters attached. Ordinary bleached oyster or other shells is such a material; bound up in fish netting bags it might be useful. Other artificial collectors are suggested by Orton (1937) and Elsey (1937).

Filling and Stocking the Tanks.

It has been found most convenient to fill the Conway tanks about the 1st of June, but the exact date of filling is governed by the occurrence of spring tides about this time. It is highly desirable to fill the tanks on a good spring tide in order to obtain "outside" sea water as far as possible. The value of such offshore water for the initial filling of breeding tanks lies in the fact that it usually contains an abundance of the minute flagellates which alone form the food of the larval oyster (see Gross 1936). Inshore waters may or may not contain flagellates in abundance, but they are frequently contaminated, often heavily, with non-motile green algae. Such non-motile forms are useless as food for developing oyster larvae, and should they become dominant in the tank water, the chances of a successful spatfall are remote. Luckily, such undesirable non-motile algae are apparently littoral forms only, as they have never been reported from offshore waters.

Each tank at Conway is stocked with about 500 adult oysters, i.e., oysters not less than about five years old. There is a good deal of evidence for the belief that such older and larger oysters produce more larvae per oyster than two- or three-year-old stock. Such a large number of stock oysters is desirable as it is fairly certain that the percentage which spawns under tank conditions is considerably smaller than that spawning in natural waters (see Hagmeier 1916). The oysters are disposed around the tank at intervals on wooden trays, each of which is 4 feet by 1 foot 6 inches and accomodates fifty oysters. These trays are raised a few inches off the tank bottom by wooden cross-pieces nailed underneath, thus allowing the material thrown out by the oysters to fall through the slatted floor of the tray and so minimize fouling in the immediate vicinity of the oysters themselves. Each tray is provided with a cover, there being a space of not less than 4 inches between the cover and the slatted floor of the tray. Various materials have been used for covering, chiefly broken and rejected pieces of asbestos sheeting. Other materials used at times are synthetic boards used for lining houses, yachts, etc. Three-ply wood is unsuitable. The covers are always coated with the lime-sand mixture and may catch a good deal of spat. The purpose of these covers is to prevent the growth of filamentous and other algae on the shells of the stock oysters. If this precaution is not taken there is nearly always a dense blanket-like growth of weed on the stock, which rapidly accumulates and is distinctly disadvantageous. Such algal

growths rapidly exhaust the tank water of nutrient salts, particularly phosphate, and may prevent the development of a satisfactory population of food organisms. Further, such blanket-like masses of weed undoubtedly have a serious effect in raising the pH of the tank water, and may also trap many thousands of oyster larvae and restrict severely the circulation of water around the spawning oysters. No effort should be spared to check the growth of such rooted algae in the tanks. For this reason, and for others, to be mentioned later, it is undesirable to have any of the previous season's tiles carrying spat in the breeding tanks, as they usually have filamentous weeds attached to their edges after a year in the tanks.

The treatment of the stock oysters before the final stocking of the breeding tanks requires careful attention if unhealthy larvae are to be avoided. At Conway during recent years, stock oysters have been obtained from the River Yealm, S. Devon, but good native stock from any other source on the British coasts should be satisfactory. When buying stock it should be remembered that it is extremely undesirable to introduce the American slipper limpet *(Crepidula fornicata)* or the American borer *(Urosalpinx cinerea)* to localities where they do not at present exist. Imported French or Dutch oysters are undesirable as stock unless they have been laid down for several seasons in this country. The main consignment of stock oysters usually arrives at Conway during the early days of May, and the oysters are put at once into one of the large tanks, which will later be used for breeding purposes. The water in this tank is part changed once or twice a week at high tide. On no account should such potential stock oysters be crowded together in small tanks with inadequate changes of water. As a further precaution to ensure the healthiness of the stock, a few hundred are usually purchased during the first week of June and are distributed between the breeding tanks.

Stock oysters procured from the Yealm in May usually put on about ¼ inch of new shell-shoot during May and early June, but caution must be used in assuming that oysters with new shell-shoot are necessarily in good condition. Shell-growth and gonad condition do not seem to be closely related, and the writer has frequently observed oysters in poor condition, and even gaping, which showed much recent shell-shoot. Fresh stock to the extent of four-fifths of our annual requirement is purchased each year. At the end of the season (September) the stock oysters remaining are relaid on our own ground in the Menai Straits, a few feet below the low-water mark of spring tides. Some of these are raked up in the following May and used again as stock. Stock oysters which have remained in the smaller tanks during the winter with frequent changes of water are usually in bad condition, do not produce many larvae, and are frequently the source of unhealthy larvae. Such oysters should be avoided. Before using as stock, it is advisable to scrub the oysters and remove encrusting organisms such as ascidians, worms, etc., as these may multiply during the breeding season. *Ascidiella* and the worms *Pomatoceros* and

Spirorbis should be particularly avoided as they breed freely in tanks, and their young, having settled among the young oysters on tiles, are difficult to remove without damage to the spat.

As already mentioned, it has been found best to fill the Conway tanks during the first few days of June. It may be necessary to modify this date in other localities where water temperatures are higher. Large liberations of oyster larvae are not to be expected until the temperature of the tank water is consistently above 17°C. Over a long period of years no large liberation of larvae has occurred at Conway before the second week in June and not usually until the third week. It is possible, however, that in favourable situations on the south and east coasts such temperatures may be reached earlier, and filling may be necessary during the second half of May.

Once filled and stocked, the Conway tanks are not usually emptied until late August or early September, when they are prepared for the beginning of the mussel cleansing season. Recent experience has shown, however, that once the spat has settled, partial or complete changes of water may be desirable. This will be dealt with fully in considering the growth of the settled spat.

Routine Observations.

The tanks having been filled and stocked routine observations are begun. These are of two kinds, those directed towards assessing the number and growth of the oyster larvae, and those concerned with the development of food organisms. Water temperatures are automatically recorded throughout the season by thermograph. In smaller tanks, Sixe's pattern maximum and minimum thermometers are used and are quite satisfactory. They are read daily at a fixed hour, 10 a.m. B.S.T. Specially made thermometers are used with the scales totally enclosed in glass tubes and mounted on ebonite without metal fittings. Thermometers of this pattern were adopted as the markings invariably come off porcelain scales and metal parts rapidly corrode, and are, in any case, undesirable.

The abundance and growth of oyster larvae may be easily determined by taking twice weekly tow-nettings with a silk net of 150 meshes to the inch, and examining the catch. More accurate methods are in use at Conway, whereby the tow-net catch is analysed into size categories, and the actual number of larvae per litre is estimated. The length of larval life is usually 7—10 days in the Conway tanks. Apart from size, the fully developed oyster larvae, ready-to-set, have other distinguishing features which make them readily recognizable (see Erdmann 1935). The chief of these is a pair of dense black eyespots, one underlying the middle of each valve of the shell. These organs are first noticeable some 48 hours or so before attachment. Freshly liberated larvae usually measure 0·18 or 0·19 mm., while fully developed ready-to-set larvae are generally 0·27—0·31 mm. It is essential to be able to estimate approximately the number and growth of the larvae present, not only to ensure that normal and sufficient

liberation of larvae has taken place, but also to allow for the addition of further clean tiles a few days before settlement, so as to catch as much spat as possible and prevent overcrowding on the tiles. A certain amount of clean, bleached oyster shell, or clean slates suspended horizontally, should be put into each tank, as, on their lower surfaces, the newly settled spat can be easily seen and their density estimated.

The abundance and quality of food organisms present in the tank water are estimated by a method of concentration and counting as described by the writer (1936), but this method could only be successfully applied by persons with a certain amount of previous experience of the kinds of small organisms which constitute the food of the larval oyster. A fairly close check on the abundance of food organisms is, however, given by the rise and fall of the pH of the tank waters. This is measured twice weekly for all tanks at Conway. A suitable set of colour standards for the measurement can be procured at a reasonable cost. The tank waters at filling usually have a pH of 8·0—8·1, and this may be expected to rise gradually during the season. In unenriched waters a peak of about 8·3—8·5 is usually reached, the abundance of nannoplankton not often exceeding 30 organisms per cubic millimetre. In enriched waters the level of pH is always higher and the enrichment has to be carefully controlled to avoid reaching values much above 8·6, which are believed to be progressively more disadvantageous to the larvae. A peak value of 8·5—8·7 usually occurs in successfully enriched tanks at Conway, associated with a level of nannoplankton of about 50—70 organisms per cubic millimetre. The density of small organisms in the tank waters may be judged fairly closely from the cloudiness of the waters. In tanks of a depth of 6 feet, with a level of 50—60 organisms per cubic millimetre, objects, such as bundles of tiles on the tank bottom, are just visible, though indistinctly. A certain amount of cloudiness is discernible with a level of nannoplankton as low as 20 per cubic millimetre. The colour of the water may vary from greyish-green to a deep olive brown depending on the kind of organism which is dominant. During the last few years at Conway minute green flagellates, 2 μ or thereabouts in size, have been abundant, and the waters have a characteristic greyish-green opalescence.

The Use of Organic Enrichment.

Organic enrichment of one of the large tanks at Conway has been carried out for three successive years, in each case giving rise to a good crop of flagellates with resulting good growth of oyster larvae. During these years the unenriched tank has also given an excellent spatfall, although the density of flagellates has invariably been considerably less, and on occasions, approached starvation level *after* the spat had settled. With the technique now employed in the unenriched tank it seems that we may expect with confidence a population of flagellates sufficiently dense to give rise to a commercial spatfall, but organic enrichment, when carefully carried out, is a definite safeguard in that

Fig. 1. Tiles carrying oyster spat from the Conway tanks planted out in cages at low water of spring tides. Note wooden racks carrying tiles in the background.

a more dense population of flagellates is obtainable with comparative certainty, and is capable of supporting an enormous population of healthy larvae (see Cole 1936). Enrichment must, however, be carefully controlled. The material found most satisfactory at Conway is the finely-ground meat of the shore crab *Carcinus*. There is reason to believe further that the heating to boiling point of the "soup" made by grinding the meat with sand and water might be advantageous, as it would destroy littoral organisms and algal spores which may develop in the tanks. The level of enrichment found satisfactory for a 90,000 gallon tank works out at an average of the meat of 12½ medium-sized crabs per day over a period of three weeks or a month. One must, however, judge each season and tank individually to some extent. As soon as the pH has reached 8·3—8·4 in a steady rise and the tank water has a definite slight cloud, then enrichment should be discontinued for a while, and stopped completely if the rise of pH is maintained. Enrichment is begun as soon as the tanks are filled, and a good population of flagellates should be obtained in the tank water by the time larvae are shed in abundance. Unfortunately it happens occasionally, as in 1937 at Conway, that the liberation of larvae is delayed by continued low water temperatures, and that they are not abundant until the middle of July. In such circumstances it is generally possible to anticipate the lateness of liberation to some extent, and it is well to discontinue enrichment for a time, and then to give a little extra over a period of, say, a week when there is a definite prospect of larvae being shed in large numbers. As mentioned earlier, large scale liberations of oyster larvae are unlikely until the water temperatures are consistently above 17°C. As soon as there are definite prospects of this level being maintained, then the final phase of enrichment may be carried through. A close watch must be kept on the pH throughout. In any scheme of tank operations it is recommended that one of each pair of tanks should be enriched.

Settlement and Growth of Spat.

Settlement of spat usually occurs during July in the Conway tanks, but may occur during late June at Lympstone. There are grounds for a belief that it might also be possible to collect spat in late August and early September at Conway, for when the tanks have to be emptied about this time of the year, there is often a good batch of larvae still swimming, which on occasions has given rise to a few spat before the tanks have been emptied. The possibility of such late sets would be increased if the tanks were given one or more partial changes of water during the spring tides of August when larvae are frequently very scarce. As Orton (1937) points out, although early spat are rightly valued on account of their rapid growth during the first season, small late-set spat may survive the winter equally well, and during the following summer the early and late sets rapidly become indistinguishable. Settlement may be concentrated into a few days as at Conway during 1936, or spread out over a period of weeks as in 1937, but its

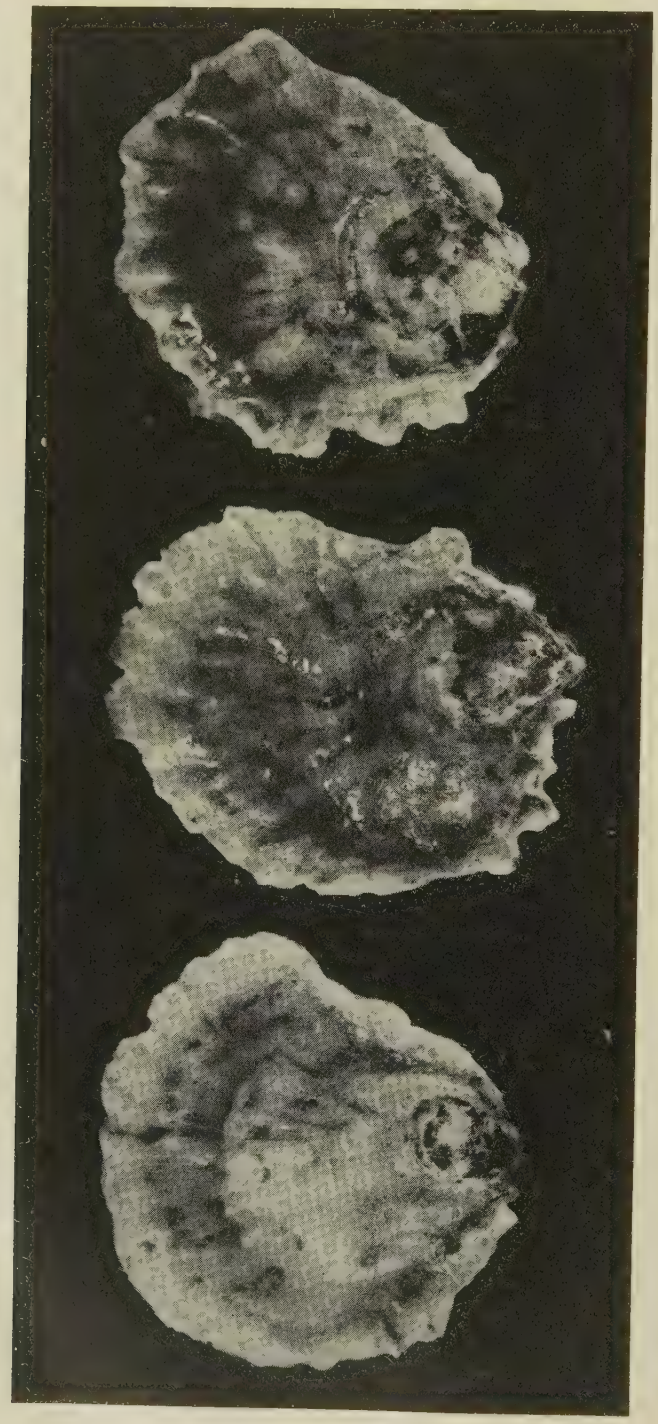

Fig. 2. Tank-bred oysters after 12 months in the sea. Settled July 1936; planted out August 1936; detached from tiles May 1937; photographed August 1937. Natural size

duration can easily be ascertained by immersing clean shells at intervals and observing the amount of spat set thereon.

The early growth of thickly set spat (i.e., several hundred per tile) varies very considerably in different seasons, depending chiefly upon the abundance of food organisms; in the stagnant waters of the breeding tanks, however, lack of water circulation beneath the tiles seems, after a while, to check the growth of the spat. It has been found better to transfer the spat within a few days of settlement to the shallow tanks available at Conway, and to give frequent changes of water from the estuary. If no such shallow tanks are available then several partial changes of water should be given to the breeding tanks after the spat has settled. The shallow tanks at Conway are just over 3 feet in depth and hold 36,000 gallons. They are usually half-changed twice a week from the estuary when containing growing spat, water of full salinity free from silt always being obtained if possible. The growth of the spat under these conditions is very satisfactory. On several occasions special large-scale cultures of organisms suitable as food for the settled spat have been prepared and inoculated into the shallow tanks (see Cole 1936), but the growth of the spat, although good, has not been significantly better than that of spat given frequent changes of estuarine water. The conclusion has been reached that the extra trouble and expense is not justified.

The Planting of Tank-bred Spat.

From a consideration of the results of planting in open water spat of ages varying from a few days to 12 months, it is the opinion of the writer that despite the satisfactory growth in the sea of very tiny spat, it is best to retain oysters in tanks until they are $1/4$—$3/8$ of an inch in diameter. This size is usually reached by the middle of August and often earlier, and the tiles are then transferred to the Ministry's relaying ground near Tal-y-foel in the Menai Straits. Experiments have been made with tiles placed on hard bottom, on wooden racks raised about two feet off the mud, and in cages covered with wire of small mesh also raised off the bottom. The best results have been obtained in wire-covered cages such as those shown in Fig. 1. These experiments are still in progress and have been designed to reveal the cheapest and most satisfactory method of dealing with spat during the interval between leaving the tanks and the stage at which they are large enough to be detached from the tiles. In France it is usual to detach spat when they are about an inch across and this size is normally reached by the spring following settlement. Thereafter, the growth of oysters should average $3/4$ of an inch per annum for the next three years, giving marketable oysters in four to six years. This rate of growth is maintained without difficulty with tank-bred spat, as is well shown by Fig. 2.

Of the wire materials used in covering cages containing tiles $1/2$-inch-mesh galvanized wire netting has proved the most satisfactory. There is, of course, much latitude for personal opinion in the construction of

Fig. 3. Close up of section of wooden racks carrying tiles. The oyster spat may be seen on the tiles in the foreground.

these cages, but there are several points which it is important to observe in their manufacture and use. If cages containing several layers of tiles are used, then the tiles should be wired together in groups of 4, 6, 8 or 10, as the case may be, to prevent movement inside the cage. The tiles should rest on wooden battens with the wire nailed outside, avoiding direct contact between tile and wire, as the constant friction soon rubs off the galvanizing material and thereafter corrosion is very rapid. All materials, both wood and wire, should be thoroughly tarred, the tar being applied hot, and a little pitch added to give increased hardness to the coating. The cages should be established at low-water mark of spring tides, so as to minimize the danger of frost. On the west and south-west coasts severe and prolonged frost is rare, and oysters left at low water of spring tides throughout the winter are unlikely to suffer damage. On the east coast, however, oysters exposed on the foreshore are liable to be killed by frost. In such localities the return of the spat to the tanks during the winter is the obvious solution. Other possibilities are the transfer of the spat to grounds on the south-west coast for the winter, or the use of submersible cages. The collection of silt on the backs and between the tiles should be prevented by periodical swillings, and a close watch should be kept for the growth of ascidians etc. on the undersides of the tiles. The tiles may remain in cages over the winter, or, if the spat have grown to a size of ¾ of an inch during the first summer and autumn, they may be placed on slatted racks without wire coverings, raised some two feet off the bottom (Fig. 3).

Detachment of spat should always be done during the spring or early summer when any damaged oysters will quickly put on new shell-shoot and repair the injury. When detached, spat should not be less than 1 inch in diameter. For detachment old table-knives with about three inches of blade serve admirably, and the ideal to be aimed at is to detach each oyster without injury. After detachment the spat may be placed fairly thickly in covered trays with bottoms of heavy gauge ½-inch-mesh wire netting, the whole being well tarred. Woven wire, galvanized after manufacture, with three meshes to the inch is even more satisfactory. Oysters can, if necessary, be grown to maturity in these trays (see Needler 1935), but it is usual to plant them on suitable bottom when they are about 2 inches across.

As an indication of the yield to be obtained from tiles under the best conditions, it may be mentioned that from nine tiles of the year, placed in a cage at the Menai Straits at low water in August 1936, 2,000 spat were detached early in May 1937, and the best of these oysters were, in August 1937, well over 2 inches across; a few of them are shown in Fig. 2. As mentioned earlier, it would probably be better to aim at rather fewer oysters per tile in order that their growth and shape may be all that could be desired.

If spat were caught on oyster shell or other culch, it would be possible to spread this over the beds at the end of the first season, omitting the period in cages, etc., but it must be remembered that such

small spat are very liable to damage from crabs and borers, as well as smothering by silt. It is the opinion of the writer that protection during the early stages is well justified. In the Menai Straits only the English smooth tingle *(Purpura)* is at all common, and no damage has been caused by this mollusc. The English rough tingle *(Ocinebra)* has been seen once or twice, but the American rough tingle *(Urosalpinx)* is unknown. If cage cultivation be carried on where these borers are abundant, then woven wire of suitably small mesh to exclude them may have to be used, although it is possible that hand-picking around the trays may be sufficient to ward off serious attacks. The question of borer control is dealt with exhaustively by Federighi (1931), and Galtsoff, Prytherch and Engle (1937), and many useful suggestions are advanced.

Practical Application of the System.

The artificial culture of oysters has been attempted on many occasions in the past both in Britain and elsewhere. Notable British attempts were those at Hayling Island about 1867, at Beaulieu in 1878, and in pits on the Essex coast at various times (see Philpots 1890). In some of these an initial success was obtained but was not repeated, and all experiments were quickly abandoned. It is not too much to say that such attempts were doomed to failure at the outset, in as much as those in charge had no knowledge of the requirements of the larval oysters as regards food or water conditions. In nearly all cases, shallow pits with earth or clay walls and mud or shingle bottoms were used. We know now from experience at Lympstone that with a comparatively small volume of water, a mud bottom is in itself sufficient to stultify the attempt under practically all circumstances, as it rapidly sets up undesirable water conditions. Nor can shallow pits be expected to yield spat in the light of our experience with their use.

In place of this widespread ignorance of the most critical phase in the life history of the oyster, we now have a solid body of knowledge concerning the requirements of both the larvae and the early spat. In no respect is our knowledge notably deficient. This knowledge has been acquired by long-continued experiment in tanks, supplemented and confirmed by small scale rearing experiments in the laboratory. It is not too much to say that the time is now ripe for further attempts at spat collection in tanks on a commercial scale, in areas adjacent to good natural growing ground. In order that such attempts should have the best possible chance of success, it is clear that at least intermittent scientific supervision is necessary. In nearly all areas where oyster cultivation is carried on there are already numerous shallow oyster pits which could be adapted to the needs of scientific oyster breeding at small cost. There are good reasons for believing that the cost of such adaptation would be repaid in a few years. When one considers that the trade in flat oysters in the British Isles is almost entirely

dependent on brood imported from France, then it is reasonable to claim that a method of artificial production such as the one described above, which has already shown commercial possibilities, warrants a thorough trial under the best conditions.

Summary.

(1) As a result of long-continued experiment at Conway, and despite general failure elsewhere in the past, the production of oyster spat on a commercial scale in tanks may be reasonably expected if close attention is paid to the factors summarized below.

(a) The provision of large, clean, well-sited concrete tanks, not less than six feet (ca. 2 metres) deep.

(b) The use of only sound, mature, well-fished breeding oysters, covered throughout the season.

(c) The use of clean offshore sea water as far as possible.

(d) The use of controlled organic enrichment to supplement the natural food supply of the larvae.

(2) The growth of the spat is most rapid when planted in natural waters, but adequate protection from enemies must be provided, especially during the first winter.

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Note.

IN his paper "Solar Radiation and its Transmission through Air and Water" (Journ. du Cons., 1932, Vol. VII, No. 2, p. 181), Dr. W. R. G. Atkins gave figures for the percentage of ultra-violet, visible, and infra-red in the solar spectrum outside the earth's atmosphere. He informs us that he cannot now trace the source of these figures, but is convinced that they are seriously in error. Having plotted Abbot's data for the extra-atmospheric solar spectrum, and measured the areas within the given limits, he obtained the following values:— 0·3 — 0·4 μ, 6·6 per cent.; 0·4 — 0·76 μ, 52·0 per cent.; 0·76 — 3·0 μ, 41·3 per cent. The figures originally given have recently been quoted by G. L. Clarke (Ecology, 1938, *19*, 103).

Reviews.

E. H. Smith, F. M. Soule, O. Mosby. "The Marion and General Greene Expeditions to Davis Strait and Labrador Sea, 1928—1931—1933—1934—1935. Scientific Results, Part 2, Physical Oceanography." U.S. Treasury Department, Coast Guard, Bull. No. 19, pp. 259, 155 figs. Washington, 1937.

Über die wissenschaftlichen Ergebnisse der "Marion"-Expedition 1928 lagen bisher zwei 1931 bezw. 1932 veröffentlichte Hefte des Bulletin Nr. 19 vor, in denen Edward H. Smith die Eisverhältnisse in der Davis-Strasse und Baffin-Bay sowie die Ausbreitung des Eises im Nordatlantischen Ozean und weiterhin Noble G. Ricketts zusammen mit Parker D. Trask die Tiefen und Bodenablagerungen in der Davis-Strasse behandelten (vgl. *Journal du Conseil*, Vol. VII, p. 409—413). Das jetzt erschienene Heft bildet den Abschluss dieser Veröffentlichung, es enthält die das Meerwasser selbst betreffenden Ergebnisse und gründet sich auf die Beobachtungen der "Marion"-Expedition 1928, vervollständigt durch die Fahrten der "General Greene" nach der Labrador-See 1931, 1933 bis 1935. Da die Gewässer nördlich von Neufundland und über der Neufundland-Bank mit denen des Untersuchungsgebietes eine Einheit bilden, sind sie in die Diskussion einbezogen; die Grundlage hierfür lieferten die Beobachtungen des internationalen Eisüberwachungsdienstes, die in den Coast Guard Bulletins 1—25 veröffentlicht sind. Der hier behandelte Teil des nordwestlichen Nordatlantischen Ozeans reicht also nach Süden soweit wie das Treibeis gelangt und nordwärts bis 70° N.-Br. zwischen Grönland und Baffin-Land. Nördlich davon sind vom Coast Guard keine Beobachtungen gesammelt worden und die darüber gegebenen Mitteilungen sind der Literatur entnommen.

Die beigegebene farbige Tiefenkarte reicht südwärts bis 40° Br., im Norden bis zum Smith-Sund und im Nordosten bis Island, sie enthält die Tiefenlinien für 200, 400, 600, 1000, 1400, 2000, 3000, 4000 und 4500 m. Die Hauptzüge der Tiefengestaltung sind folgende. Der Boden des Baffin-Meeres bildet eine bis über 2000 m. tiefe Mulde, die durch die Davis-Strasse mit einer Schwellentiefe von etwa 675 m. Tiefe von den grösseren Tiefen der Labrador-See und des übrigen Nordatlantischen Ozeans weitgehend abgeriegelt ist. In der Labrador-See, dem südlich der Davis-Strasse zwischen Grönland im Nordosten und Labrador im Südwesten gelegenen Meeresgebiet, senkt sich der Boden langsam nach Südosten. Der in etwa 50° Br. vermutete Neufundlandrücken besteht nicht, wie nunmehr durch die Lotungen des "Meteor" und insbesondere durch die eingehende Lotungsarbeit der "General Greene" als nachgewiesen anzunehmen ist. Zwischen dem Labrador- und dem Neufundland-Becken besteht durch eine allerdings schmale, aber über 4500 m. tiefe Rinne Verbindung bis in die grössten Tiefen. Der dem Festlande vorgelagerte Schelf ist auf der grönländischen Seite nur schmal, dagegen

auf der amerikanischen Seite breit und dort auch mannigfach gegliedert, was sich für die Ausbildung der dortigen hydrographischen Verhältnisse als von Bedeutung erweist.

Der hydrographischen Diskussion ist eine sehr willkommene Zusammenstellung der bisher in dem betrachteten Gebiet ausgeführten Untersuchungen vorangestellt sowie eine Darstellung der angewandten Arbeitsmethoden. Daraus geht hervor, dass erhebliche und in ihren Ursachen nicht immer aufgeklärte Schwierigkeiten mit den Wasserschöpfern bestanden haben und auch in der Salzgehaltsbestimmung durch Titration und mit der elektrischen Methode. Auch wurden erst auf den letzten Fahrten der "General Greene" die Messungen der Tiefentemperaturen und die Bestimmung der Tiefen mit Hilfe von ungeschützten Thermometern so genau durchgeführt wie es die heute entwickelte Methodik ermöglicht. Von der Methode der Berechnung der Strömungen aus der Dichteverteilung wurde weitgehend Gebrauch gemacht. Da sichere Annahmen über eine bewegungslose Schicht nicht möglich waren, musste von der Berechnung von Absolutwerten der Geschwindigkeit abgesehen werden, es wurden statt dessen die relativen Wasserbewegungen im Verhältnis zu denen in einer einheitlichen Bezugsfläche festgestellt; als diese wurde meist die 1500-Dezibarfläche gewählt, weil wenigstens bis zu dieser Tiefe an den meisten Stationen die Beobachtungen durchgeführt worden sind, in manchen Fällen die 1000- oder 2000-Dezibarfläche.

Die hydrographischen Verhältnisse vor der westgrönländischen Küste wurden am vollständigsten erfasst im Sommer 1928 und zwar durch sieben etwa gleichabständige Schnitte senkrecht zur Küste zwischen Kap Farewell und der Insel Disko, aber auch aus den Jahren 1931, 1933, 1934 liegen aus dem südlichen Teil dieses Gebietes einige Schnitte vor. Daraus ergibt sich, dass sich der von Osten um Kap Farewell vordringende Ostgrönlandstrom, der durch eine Abzweigung des Irmingerstromes verstärkt ist, an der Westküste Grönlands nordwärts bewegt als Westgrönlandstrom. Auf weite Erstreckung hin sind beide Wasserarten dieser Strömung feststellbar, nämlich das küstennahe kühle und salzärmere aus dem Ostgrönlandstrom stammende arktische Wasser und das von der Küste weiter entfernte wärmere und salzreichere atlantische Wasser, das auf den Irmingerstrom zurückzuführen ist und das sich in seiner reinsten Ausbildung in 100 bis 150 m. Tiefe befindet. Aus den mehrfachen Wiederholungen der Beobachtungen geht hervor, dass die Schwankungen der Ausdehnung und Geschwindigkeit des Westgrönlandstromes besonders in seinem arktischen Teile von Jahr zu Jahr recht beträchtlich sind. Im Laufe des Jahres ändert sich die Temperatur des Westgrönlandstromes in der Achse seines atlantischen Teiles von etwa 4° C. im Februar bis über 8° im September und in seinem arktischen Anteile von — 1·3° am Ausgang des Winters auf 3 bis 4° am Ende des Sommers. Der Westgrönlandstrom setzt sich auch an der Ostseite der Davis-Strasse nordwärts fort und ist bis 500 m. Tiefe nachzuweisen, auf ihn ist die Entstehung der warmen Zwischenschicht der Baffin-Bay zurückzuführen.

Die Verhältnisse vor der amerikanischen Küste von der Davis-Strasse bis Kap Race sind besonders im Sommer 1928 eingehend untersucht worden, es liegen aus dieser Zeit zehn Schnitte senkrecht zur Küste vor. Das Gebiet ist im Norden beherrscht durch den Baffin-Land-Strom und vor der Küste von Labrador durch den Labradorstrom. Der letztere bildet die Fortsetzung des ersteren, trotzdem sind zwei verschiedene Bezeichnungen angewandt, weil der Labradorstrom durch westwärts gerichtete Abzweigungen des Westgrönlandstromes erheblich verstärkt wird und zwar verhalten sich die Anteile des Baffin-Land-Stromes und des Westgrönlandstromes am Labradorstrom

etwa wie 2 : 3. Die nähere Betrachtung hat ergeben, dass der Labradorstrom an zwei Stellen, über dem Schelf und über dem Kontinentalabhang, am stärksten ausgebildet ist, die in beiden Teilen des Labradorstromes verfrachteten Wassermengen verhalten sich etwa wie 1 : 3. Im Bereich der Neufundland-Bank bewegt sich der Labradorstrom vor allem im Gebiet des Ostabfalls der Bank südwärts, bis er bei Annäherung an den Golfstrom absinkt. Die Verhältnisse in der Tiefe sind erfasst durch sieben senkrecht zur Neufundland-Bank gelegte hydrographische Schnitte, die deutlich zeigen, dass der Labradorstrom sich eng an den Abfall der Neufundland-Bank anschmiegt und dort im Mittel bis etwa 950 m. nachweisbar ist. Weiter seewärts bewegt sich atlantisches Wasser nordwärts, sodass dort grosse horizontale Temperatur- und Salzgehaltsgradienten in östlicher Richtung auftreten, die mit wachsender Tiefe schnell kleiner werden. Die aus den nun schon langjährigen Beobachtungen des Internationalen Eisdienstes festgestellten Schwankungen des Labradorstromes im Bereiche der Neufundland-Bank sind von grösster praktischer Bedeutung wegen ihres Einflusses auf die Verbreitung der Eisberge, wie S m i t h früher schon dargelegt hat. Die unperiodischen Schwankungen des Labradorstromes von Jahr zu Jahr sind so bedeutend und unregelmässig, dass die bisher gewonnenen Beobachtungen nicht ausreichen, den Anteil des jährlichen Ganges an den Schwankungen festzustellen.

Die quantitative Betrachtung der oberhalb von 1500 m. (der Bezugsfläche für die dynamischen Berechnungen) insgesamt in die Labrador-See hinein- und wieder hinausgeführten Wassermenge und auch der Wärmeverhältnisse führt zu der Auffassung, dass sich in grösseren Tiefen beträchtliche Wassermengen aus der Labrador-See südwärts nach dem Atlantischen Ozean bewegen müssen. Das Absinken dieses Tiefenwassers findet im Westen von Südgrönland statt infolge Abkühlung der oben genannten nach Nordwesten vordringenden Abzweigung des Irmingerstromes. Es bewegt sich in der Tiefe vor allem an der amerikanischen Seite des Labradorbeckens südwärts und zwar in nach gleicher Richtung zunehmender Tiefe von 2500 bis 3500 m.; auf den Salzgehaltsschnitten hebt es sich als Zone maximalen Salzgehalts heraus. Unterlagert ist dieses Tiefenwasser von salzärmerem und kälterem Bodenwasser, dessen Bildung in den zentralen Teilen der Labrador-See im Winter erfolgen dürfte. Es ist wahrscheinlich, dass dieses Bodenwasser sich ebenfalls südwärts in den Nordatlantischen Ozean bewegt.

Ein reiches Beobachtungsmaterial ist durch die vorliegende Veröffentlichung nach sorgfältiger Diskussion zugänglich geworden und unsere Auffassungen von den Wasserbewegungen im Raume zwischen Grönland und Nordostamerika sind wesentlich geklärt und vertieft. Trotzdem ist lebhaft zu wünschen, dass die Beobachtungen systematisch fortgesetzt und zwar besonders auf die meteorologisch ungünstigeren Jahreszeiten ausgedehnt werden, um die wegen der Verfrachtung von Eisbergen praktisch bedeutungsvollen Schwankungen der Strömungen von Jahr zu Jahr und innerhalb des Jahres zu erfassen und manche weiteren noch offenen Fragen zu klären.

Bruno Schulz.

P. E. Church. "Temperatures of the western North Atlantic from thermograph records." Assoc. d'Océanogr. Phys., Publ. Sci. No. 4, pp. 32, 8 figs. Liverpool, 1937.

Die Schrift behandelt die Ergebnisse der Bearbeitung von rund 1200 Thermographenstreifen, die auf Schiffen zwischen der Ostküste der U. S. A. und Westindien (auch bis Kap San Roque) in den Jahren 1926—1935

gewonnen worden sind. Die Registrierung der Wassertemperaturen betrifft also nicht die eigentliche Wasseroberfläche, sondern Tiefen etwa zwischen 3 und 8 m., womit Vorteile und Nachteile verbunden sind; hierzu mag man u. a. J. R. Lumby's Ausführungen (*Journal du Conseil*, Vol. III, S. 385) lesen. Im Hinblick auf Scherhag's Aufsatz über die Erwärmung der Arktis (*Journal du Conseil*, Vol. XII, S. 269) wäre es — vielleicht — lohnend zu untersuchen, ob die nach G. Slocum's Material festgestellte Erwärmung im Ursprungsgebiet des Golfstromes sich auch durch das Thermographenmaterial bestätigen lässt oder nicht. Church gibt hierzu zwar keine Bemerkung, aber er hat nichtveröffentlichte synoptische Karten von Woche zu Woche gezeichnet.

Ähnlich wie C.o'D. Iselin in seiner Untersuchung über die Zirkulation des westlichen Nordatlantischen Ozeans (vergl. *Journal du Conseil*, Vol. XII, S. 80, die Besprechung durch G. Dietrich), unterscheidet Church 5, bezw. 6 verschiedene Wasserkörper, allerdings nur an der Hand der Temperaturverhältnisse; nämlich das Küstenwasser (Schelfwasser bis etwa zur 200 m. Linie), das Wasser über dem Kontinentalabfall (*slope water*) bis etwa zur 2000 m. Tiefenlinie, das Wasser des kalten Walls — diese sehr schmale Zone hat Iselin S. 11 nicht besonders abgebildet —, das Golfstromwasser, das Wasser des zentralen Atlantischen Ozeans = Sargasso See, und endlich das Wasser des Nordäquatorialstromes.

Von wesentlichen und neuen Darlegungen sei angeführt, dass im *slope water* zeitweise eigenartige wirbelnde Warmwasserinseln oder Warmwasserflecke von begrenzter Lebensdauer zu beobachten sind, die wohl vom Golfstrom stammen, aber, weil seinem Bereich entrückt, nur ganz langsam ihre Lage verschieben. Ferner liegt nach Church der kalte Wall im engeren Wortsinn weitab von der Küste, ist nur 10 bis 20 Seemeilen breit und "offenbar die Folge von Auftrieb"; doch gibt der Verfasser nichts darüber, unter welchen dynamischen Verhältnissen dieser Vorgang hier zu Stande kommen soll. Übrigens hat keine Thermographenaufzeichnung jemals solch krassen Wärmewechsel angezeigt, wie er nach Schiffsberichten, die bis zu 11° Differenz auf 75 m. Entfernung meldeten, auftreten soll.

Dem Golfstrom gibt Church im Südosten von Kap Hatteras eine Breite von 50 Seemeilen, unter 65° W.-Lg. (Halifax-Länge) eine solche von nur 62 Sm. Unperiodische starke örtliche Verlagerungen kommen vor, aber die jahreszeitlichen sind im Mittel sehr gering. Charakteristisch ist hier auch die geringe jährliche Amplitude der Temperatur, wie eine Figur anschaulich macht.

Nach Ausführungen über die Wärmeverhältnisse des Sargasso-Meeres kommen noch Angaben über das Wasser des Nordäquatorialstromes, das der Verfasser in 3 Unterteile gliedert, einen nördlichen etwa vom Wendekreis bis 15° N.-Br., einen mittleren von da bis 7° N.-Br. Was im Süden davon nach WNW. strömt, zeigt schon thermische Einflüsse südhemisphärischen Charakters, bei Geschwindigkeiten bis 2·4 Knoten.

Viele Schlussfolgerungen wären natürlich wesentlich stärker gestützt, wenn das Material wenigstens teilweise hätte durch gleichzeitige Salzgehaltsbestimmungen ergänzt werden können. Dass aber ein solcher Wunsch bei der ganzen Art des Betriebes an Bord von Handelsschiffen sehr schwer erfüllbar ist, braucht kaum bemerkt zu werden.

G. Sch.

A. Jakhelln. "Oceanographic Investigations in East Greenland Waters in the Summers of 1930—1932." Skrifter om Svalbard og Ishavet. Nr. 67, pp. 1—79, 28 figs., 2 pl. Oslo, 1936.

Die hydrographischen Stationen der "Polarbjørn" aus dem Gebiet des Kaiser Franz Josef-Fjordsystems, die vornehmlich im August 1930, 31, 32 von Jakhelln durchgeführt wurden, werden nach sorgfältiger Aufbereitung tabellarisch wiedergegeben. Eine verbesserte Tiefenkarte des ostgrönländischen Schelfgebietes zwischen 72°—75° N. mit seinen submarinen Fjorden ist beigefügt.

Die Bearbeitung zerfällt in eine mehr dynamische Untersuchung des Ostgrönlandstromes vor dem Fjord und in eine vorwiegend hydrographische Untersuchung der Verhältnisse im Fjordsystem selbst. Über dem warmen atlantischen Wasser strömt keilförmig über dem Grönlandschelf das kalte salzarme Polarwasser des Ostgrönlandstromes nach Süden. Sein Transport wird mit der neuen, einfachen Methode von Jakhelln (Geofys. Publ., Vol. XI, Nr. 11, Oslo, 1936) berechnet, wobei allerdings die "Nullfläche" der Bewegung horizontal in 250 m. Tiefe angenommen wird, während die hydrographische Grenze zwischen polarem und atlantischem Wasser von 200 m. schnell gegen den Ozean ansteigt. Aber die Unterschiede der berechneten Transportmengen zwischen zeitlich verschiedenen Schnitten dürfte dadurch kaum betroffen werden. Gegenüber $1{\cdot}32 \times 10^6$ m.^{3}/sec. im Sommer 1905 auf Grund der "Belgica"-Beobachtungen wird für den Sommer 1932 der verstärkte Transport von $1{\cdot}60 \times 10^6$ m.^{3}/sec. berechnet.

Bezeichnend für die Sauerstoffverteilung im Ostgrönlandstrom wie in den Fjorden ist die starke Übersättigung in 10—25 m. (bis 116 %), die auf photosynthetische Prozesse des Phytoplanktons zurückgeführt wird. Grad und Ausdehnung der Übersättigung weist einen engen Zusammenhang mit dem Aufbrechen des Eises im Sommer auf.

Das Fjordwasser zeigt unter einer dünnen Schmelzwasserdecke polares und atlantisches Wasser ähnlich den Verhältnissen vor dem Fjord, nur dass die unteren Schichten durch die Satteltiefe bestimmt sind. Die stärkere Durchmischung des polaren Wassers in den Fjorden, die Jakhelln aus den $S = f(t)$-Kurven ableitet, wird mit der langsamen Erneuerung erklärt, die schubweise erfolgt und mit den jährlichen Geschwindigkeitsschwankungen des Ostgrönlandstromes in Zusammenhang gebracht wird.

Auffallend ist die gute, wenn auch im einzelnen unterschiedliche Durchlüftung des ganzen Fjordsystems, obwohl geringe Satteltiefen die inneren Rinnen abschliessen. Die verstärkte Turbulenz durch interne Wellen wird als Erklärung herangezogen, die insofern begründet erscheint, als tatsächlich an vier Wiederholungsstationen im Clavering Fjord starke vertikale Verlagerungen im Aufbau (20 m. in 100 m. Tiefe) beobachtet wurden. Im unmittelbaren Zusammenhang mit dieser Erklärung steht die Begründung der verschieden starken Durchlüftung einzelner abgelegener Fjordzweige. Es wird vermutet, dass die internen Wellen und damit die Turbulenz in den einzelnen Fjorden verschieden stark ausgebildet sind, je nach der Fjordtopographie.

Diese interessanten Probleme eines inneren Zusammenhanges von Durchlüftung und internen Wellen, die Jakhelln in seiner aufschlussreichen und vielseitigen Arbeit anschneidet, können nur durch weitere Beobachtungen der Lösung zugeführt werden.

G. Dietrich.

W. Hansen. "Die Strömungen im Barents-Meer im Sommer 1927 auf Grund der Dichteverteilung." Arch. Deutsch. Seewarte, Bd. 55, Nr. 5, S. 1—41, 4 Taf., 43 figs. Hamburg, 1936.

The results of the hydrographic investigations of the "Poseidon" in the western part of the Barents Sea in 1927 were discussed by Professor B. Schulz in a publication in 1929. At his request the observations were taken up again by Dr. W. Hansen for dynamic treatment, aiming at a picture of the current system.

The relatively shallow Barents Sea, with depths rarely greater than 400 m., presents interesting difficulties, specially connected with the great variation of bottom depth from station to station. The author has constructed sections of the distribution of current components, computing by the ordinary methods (Helland-Hansen's formula) the currents at different depths on the assumption of zero current at the greatest depth of observation common within each pair of stations. With our present knowledge of ocean currents this assumption of zero current near the bottom at variable depths does not appear to agree very well; in many cases a clear tendency for the currents to follow the slope of the bottom along a coast can be traced, for instance, in the areas near Newfoundland, in the Norwegian Sea, and north of Spitsbergen. The extrapolation method of Helland-Hansen and Nansen, using imaginary values below the bottom at the shallow stations, would here probably bring about a more correct picture, although all theories are of a greatly limited validity in cases like this.

By a thorough study of the observations the author finds a very pronounced parallelism between isotherms, isohalines, and isopycnals, and also isobaths of the bottom. In order to obtain horizontal pictures of the currents, he then uses a very simple method, constructing iso-lines based on the average density, for instance, between 75 m. and the bottom at the different stations. The use of the density values instead of the dynamic depths of the different isobaric surfaces, as previously used by Nansen, should in itself hardly bring important errors at the moderate depths here in question. But bringing together these density averages as comparable is not correct in principle, because the density on the whole increases with depth and the averages must, therefore, also increase with the bottom depth. Imagine a basin with motionless water of the same temperature and salinity all over at the same depth, but with different values at different depths; the method described would here lead to a cyclonic circulation.

I should think, though, that the chief features of the current system deduced may on the whole be fairly near to the actual conditions; the author does not claim the details to be trustworthy. Several characteristic features of the picture obtained seem to agree with the current charts of the Barents Sea constructed by A. Sokolow in 1931 from Russian hydrographic observations; it appears that the conditions must be very complicated. The old picture of N. Knipowitsch, with the finger-like branching of the North Cape Current into the Barents Sea, may still be upheld on the whole, but the branches do not appear stable in position. It seems to me reasonable that the branches may, in different years, be situated farther north or south, and be more or less developed.

Håkon Mosby.

A. E. Parr. "On the Longitudinal Variations in the Dynamic Elevation of the Surface of the Caribbean Current." Bull. Bingham Oceanogr. Collect., Vol. VI, Art. 2, pp. 20, 7 figs. New Haven, Conn., 1937.

Die dynamische Topographie der Meeresoberfläche, bezogen auf die 1200 Dezibarfläche im Karibischen Meer und in der Cayman-See, zeigt in Profilen längs des Hauptstromstriches des Oberflächenstromes die auffallende Erscheinung eines kräftigen Anstieges um 30 bis 40 dyn. cm. bis zur Jamaica-Honduras-Schwelle, dann einen Abfall in der Cayman-See um etwa 10 dyn. cm., um dann wieder bis zur Yucatan-Schwelle um 15 bis 20 dyn. cm. anzusteigen, sodass die Topographie der Meeresoberfläche und der Druckfläche im wesentlichen der Bodenkonfiguration längs des Hauptstromstriches folgt. Hand in Hand damit geht ein Abfall der Isothermen und Isohalinen bis zur Honduras-Schwelle, dann ein Anstieg über dieser und ein Abfall in der Cayman-See. Parr will in oben zitierter Abhandlung eine Erklärung erstens für den Anstieg der Druckflächen und der Meeresoberfläche längs des Hauptstromstriches der Karibischen Strömung, zweitens für die Aufwölbung der Druckflächen über den zwei Schwellen geben. Zum ersten Punkt ist zunächst zu bemerken, dass es sehr schwer ist, ohne spezielle Untersuchungen den "Hauptstromstrich" einer Meeresströmung ohne weiteres festzulegen und für ihn dann die topographische Lage der Druckflächen und der Meeresoberfläche genau anzugeben. Weiter entwickelt Parr theoretische Überlegungen für den Fall, dass in einer homogenen bezw. in einer geschichteten Wasserschicht durch Windeinfluss von oben eine Beschleunigung der oberen Wassermassen einsetzt und leitet daraus die Form von Druckflächen und die Lage der Grenzflächen innerhalb der Wasserschichten ab. Seinen qualitativen Schlüssen kann man in allen Phasen nicht folgen, und sie würden an Überzeugungskraft gewiss gewinnen, wenn sie durch quantitative dynamische Durchrechnung des Falles gestützt werden könnten. Aber auf jeden Fall geht es nicht an, dabei die ablenkende Kraft der Erdrotation völlig aus dem Spiele zu lassen; denn so schmal ist sowohl die Karibische wie Cayman-See nicht, dass man ihren Einfluss ganz vernachlässigen kann. Im wesentlichen dürfte wohl der Anstau der mit kräftiger Geschwindigkeit herangeführten Wassermassen des Karibischen Stromes an der Honduras-Jamaica-Schwelle die Anhäufung der oberen leichteren Wassermassen davor und dadurch auch den Anstieg der Druckflächen und der Meeresoberfläche erklären. Der zweite Punkt findet seine naheliegende Erklärung in der Beeinflussung einer starken Strömung durch die Topographie der Bodenkonfiguration, wofür theoretisch-quantitative Durchrechnungen bereits vorliegen.

A. Defant.

H. R. Seiwell. "Short Period Vertical Oscillations in the Western Basin of the North Atlantic." Pap. in Phys. Oceanogr. and Meteor., Vol. V, No. 2, pp. 44, 9 figs. Cambridge and Woods Hole, Mass., 1937.

Das amerikanische Forschungsschiff "Atlantis" hat in der Zeit vom 9. Juli, $9^h.\ 30^m.$ bis zum 13. Juli 1936, $15^h.\ 45^m.$ auf der mittleren Position 66°25′ W., 35°07′ N. auf Station 2639 vier und vierzig ozeanographische Serien ausgeführt. Das Schiff war *nicht* verankert und musste mehrfach durch Fahrt auf nahezu gleicher Position gehalten werden. In der oben erwähnten Abhandlung unterzieht Seiwell die gewonnenen Beobachtungen einer eingehenden Analyse, insbesondere in bezug auf die vorkommenden Schwankungen der Temperatur und des Sauerstoffes. Salzgehaltsbestim-

mungen scheinen nicht oft genug vorgenommen zu sein, um auch die Schwankungen dieses Elementes gesondert zu studieren. Die Temperaturschwankungen sind von derselben Grössenordnung wie die von Helland-Hansen und Nansen auf "Michael Sars" und "Armauer Hansen" und von der Deutschen Atlantischen Expedition auf den Ankerstationen des "Meteor" gefunden worden sind. Sie scheinen hier recht unregelmässig in Zeit und Amplitude zu sein, und man ist nicht ganz sicher, ob diese Unregelmässigkeit etwa eine Folge des Umstandes sein könnte, dass das Schiff nicht verankert war. Auf dem "Meteor" haben wenigstens alle Stationen bei nicht verankertem Schiff recht unregelmässige Schwankungen der ozeanographischen Elemente ergeben, während jene vom verankerten viel gleichmässiger abliefen. Die ozeanographische "Umwelt" der Station 2639 ist zwar eine ganz andere als bei den "Meteor"-Stationen, aber ich glaube, dass auch im Stromsystem des Golfstromes, das sicher sehr grossen Schwankungen unterliegt, Untersuchungen zur Erfassung dieser Schwankungen eigentlich nur vom verankerten Schiff unternommen werden dürfen. Die von Seiwell gegebene Analyse ist recht interessant und zeigt wie unangenehm die auftretenden kurzperiodischen Schwankungen der ozeanographischen Elemente bis in grosse Tiefen sind, will man dynamische Berechnung der Stromgeschwindigkeiten und dergleichen vornehmen. An einem numerischen Beispiel wird die Diskrepanz der Berechnung deutlich vor Augen geführt. Es ist ja klar, dass solche Berechnungen nicht viel bedeuten; denn wenn so bedeutende Schwankungen in t und S vorkommen, so besagt dies doch dass der Zustand an der Station weit entfernt ist, stationär zu sein; aber nur bei stationären Bewegungen kann die übliche Berechnung nach der Bjerknes-Helland-Hansen'schen Formel vorgenommen werden. Wir müssen uns allmählich daran gewöhnen, in den ozeanischen Strömen recht unregelmässige turbulente Wassertransporte zu sehen, die vielleicht weiter vom stationären Zustand entfernt sind, als wir im allgemeinen annehmen.

A. Defant.

G. Dietrich. "'Die dynamische Bezugsfläche', ein Gegenwartsproblem der dynamischen Ozeanographie." Ann. d. Hydr. usw., LXV. Jahrg., H. XI, S. 506—19, Abb. 4. Berlin, 1937.

Dietrich draws attention to the difficulties which are encountered when computing currents on the basis of hydrographic data. He shows especially that considerable uncertainties are introduced owing to the existence of internal waves and draws attention to the well-known difficulty of defining a surface to which currents can be referred when computed by means of the simplified theorem of circulation.

It is customary to select as reference surface a horizontal surface at great depth, not only, as Dietrich states, because one may assume the velocities to be small at great depths, but because one may also assume the absolute variations in a horizontal direction to be small. The latter assumption is essential, since in most cases we are interested in differences and since the differences of the computed *relative* velocities are significant only if the absolute variations of the velocities at the reference level are small.

Instead of introducing an "absolute" reference surface which is assumed to be nearly at rest, Dietrich advocates use of a reference surface which in each case shall be determined by means of hydrographic conditions (des hydrographischen Aufbaus). He draws attention to the fact that from the hydrographic condition one can draw conclusions as to the existence of

boundary regions between different branches of the circulation, but he is aware of the difficulty that nothing is known as to the motion of the boundary layers themselves.

When dealing with the Gulf Stream area off the east coast of the United States, Dietrich appears to recognize the validity of the objections which Rossby and Iselin have advanced against taking the oxygen minimum layer as a layer of no motion, but he thinks that the layer should be retained as a reference level and considers the computed transports as applicable to the branch of the circulation above the boundary layer. However, if this application is to have a meaning, and especially if differences in the computed transports are to be significant, the motion of the boundary layer must remain nearly constant in the direction of flow, which is contrary to the opinion of Rossby and Iselin.

Although Dietrich admits that a layer of oxygen minimum cannot generally be introduced as a layer of no motion, he adheres to the "dynamic" explanation according to which the oxygen-minimum layer is a layer of minimum motion. He attempts to refute the view which has been advanced by H. R. Seiwell, who considers the oxygen minimum layer as a result of the relation between oxygen replenishment to a given water mass and oxygen consumption within that water mass. When doing so, Dietrich states that the "dynamic" explanation of the oxygen minimum is based on the as yet qualitative conception that, except in the upper layers, the oxygen consumption due to sinking detritus is relatively independent of depth. The layer of relatively small replenishment by advective processes (small horizontal flow) must therefore be characterized by oxygen minimum.

The reviewer cannot follow this reasoning. We must assume that in the ocean the oxygen distribution is stationary, meaning that at any given locality the oxygen content remains constant or, in other words, the time change is zero. This again means that the net amount of oxygen which in a given time is supplied to a given volume by physical processes must be equal to the amount which in the same time and volume is consumed by processes of oxidation. Below the upper layers replenishment and consumption must be identical at all depths. Therefore, if the replenishment shows a minimum at any level, the consumption must also be at a minimum at this level and cannot be "relatively" independent of depth. Dietrich's formulation of the "dynamical" explanation is therefore based on conflicting ideas and his further arguments lose their foundation. *H. U. S.*

N. W. Rakestraw and **H. P. Smith.** "A Contribution to the Chemistry of the Caribbean and Cayman Seas." Bull. Bingham Oceanogr. Collect., Vol. VI, Art. 1, pp. 1—41, 32 figs. New Haven, Conn., 1937.

Nachdem A. E. Parr in einer hier kürzlich referierten Veröffentlichung[1]) über die physikalisch-hydrographischen Untersuchungen der Forschungsfahrt der "Atlantis" im Amerikanischen Mittelmeer berichtet hat, legen N. W. Rakestraw und H. P. Smith nunmehr die Ergebnisse der auf derselben Fahrt gewonnenen *chemischen* Beobachtungen vor; die Werte selbst sind bereits im *Bulletin Hydrographique* für 1933 veröffentlicht worden. Die Verteilung von Phosphat, Nitrat, pH und der aus dem pH nach dem Verfahren von K. Buch und Mitarbeitern berechneten CO_2-Faktoren wird an Hand von Vertikalkurven, von 24 Karten und 8 Schnitten diskutiert.

[1]) Vergl. Journ. du Conseil, Vol. XII, No. 3, S. 341.

Der allgemeine Verlauf der Vertikalkurven entspricht der auch sonst im Atlantischen Ozean gefundenen Verteilung. Bemerkenswert ist es, dass das intermediäre Maximum des Phosphats und Nitrats im Durchschnitt wieder etwas tiefer liegt als das Sauerstoffminimum. Das Verhältnis zwischen Nitrat-N und Phosphat-P im Tiefenwasser war mit 16 : 1 etwas niedriger als auf den früheren Fahrten im Nordatlantischen Ozean.

Im ganzen ist die Karibische See reicher an Nährstoffen als der ausserhalb liegende Ozean, sie ist offenbar ein Gebiet stärkerer P- u. N-Regeneration. In der Maximumschicht, die in etwa 800 m. Tiefe liegt, finden sich Nährstoffgehalte von über 2·0 mg.-Atom P und über 30 mg.-Atom N pro $m.^3$ (d.h. über 60 mg. P bezw. über 400 mg. N pro $m.^3$), während im Nordwestlichen Atlantik in der Maximum-Schicht die entsprechenden Werte nur etwa halb so gross sind. Die pH-Werte und die übrigen CO_2-Faktoren bestätigen erwartungsgemäss das Bild, das sich aus der Verteilung der Nährstoffe ergibt.

Zwecks Charakterisierung der verschiedenen Wasserarten wurden ausserdem die Beziehungen $P = f\ (t°)$, $N = f\ (t°)$ und $pH = f\ (t°)$ sowie die entsprechenden Funktionen zum Salzgehalt gezeichnet. Auf diese Weise konnte der verschiedene hydrographisch-chemische Aufbau von Sargasso-, Karibischer- und Cayman-See sehr schön aufgezeigt werden. Dabei ergab sich, dass der östlichste Teil der Karibischen See gänzlich aus dem sonst sehr einheitlichen Aufbau herausfällt, ohne dass dafür bisher eine eindeutige Erklärung gefunden werden konnte. Diese Eigenart des östlichsten Nord-Süd-Profils wird besonders anschaulich in den Vertikalschnitten des Phosphats: Im Süden P-Armut, in der ganzen Wasserschicht im Norden ein unverhältnismässig intensives und ausgedehntes P-Maximum, das von 500 m. bis 3000 m. reicht. Offenbar liegen in diesem Gebiet besondere biologische (und hydrographische?) Verhältnisse vor.

Die intensive chemische Erforschung dieses tropischen Meeresgebietes hat wieder mit grosser Deutlichkeit erwiesen, wie nützlich derartige Untersuchungen, abgesehen von ihrer biologischen Bedeutung, zur Charakterisierung der Wassermassen und für die Deutung der Bewegungsverhältnisse sind.

H. W.

W. R. Taylor. "Marine Algae of the Northeastern Coast of North America." Univ. of Michigan Studies, Sci. Ser., Vol. 13, pp. IX—427, 60 pl. University of Michigan Press, Ann. Arbor, 1937. ($ 5).

Earlier workers recognized that Cape Cod constitutes a point of division between a northern flora with sub-arctic tendencies and a southern flora adapted to warmer waters. A somewhat closer ecological analysis than they attempted is now made by Taylor, on a basis suggested by the paper of Börgesen and Jonsson on the distribution of the Marine Algae of the Arctic Sea and of the northernmost part of the Atlantic.[1])

For the benefit of those less familiar with the area, a map would have served a useful purpose, especially if the addition of symbols had indicated the position of the commoner algae.

The discussion of the geographical distribution of the plants is followed by careful notes on the collection and preservation of specimens. The author then discusses the purpose and limitations of the volume and points out that though an unpublished manuscript by the late F. S. Collins has been at his disposal, the present volume must not be regarded merely as a revision

[1]) Bot. of the Faeröes 3.

of that manuscript. A much wider geographical area has now been covered and in addition most of the commoner species have been re-described from American material. Generic and family descriptions have been revised in the light of modern studies on the life-cycles of the plants and the anatomy of the reproductive organs. Such revision has necessarily resulted in the need for changes in the classification and, in the Phaeophyceae, the author appears to have adopted the grouping suggested by Kylin in 1934.[2] A systematic list is given of the algae described, together with a descriptive catalogue which includes keys to the orders, families, genera and species. In the descriptions of the species, mention is made of the localities from which the plants have been recorded and a list of references is given for each species. This latter includes references to the two important American exsiccatae. Algae Exsiccatae Americae Borealis by Farlow, Anderson and Eaton, and Phycotheca Boreali-Americana by Collins, Holden and Setchell, together with citations of relevant morphological papers and of those bearing on the life-cycle of the plants. This is a somewhat unusual feature in a systematic handbook but is one which is obviously of great value to the student.

The book concludes with a comprehensive bibliography and 60 plates which have been beautifully executed by Chin Chih Jao. These latter are of exceptional quality both when they represent external morphology and more detailed structure.

It is more than 50 years ago since Farlow wrote his Handbook of New England Algae and since then no systematic account of these plants has appeared from North America. Professor Taylor's volume will consequently be very warmly welcomed by algologists, not only in the area concerned but also in Europe. The check list at the beginning enables one to see at a glance whether or not any given genus or species is included in the book, and the setting out of the algae in this form makes the more striking the complete absence of whole orders of plants which are common in Europe, as for example the Cutleriales, Dictyotales and Sporochnales in the Phaeophyceae. The book is an important contribution to algal literature and the author is to be congratulated on having produced a volume which will be of value not only to systematists but to all students of marine algology.

L. N.

S. G. Gibbons. "*Calanus finmarchicus* and other Copepods in Scottish Waters in 1933." Fisheries, Scotland, Sci. Invest., 1936, No. II. pp. 37, 2 figs., 6 charts. Edinburgh, 1936.

In this, his second paper on the occurrence of *Calanus finmarchicus* in Scottish waters, Dr. Gibbons has furnished a further set of observations based on collections made in 1933. In his introductory remarks he says that "our data, extensive though they are, must be accumulated and increased, and this report is intended as a step in this direction." This defines the scope of the paper which must not be looked on as more than a number of more or less unconnected observations. These will ultimately have to be brought together and reconciled when the main question comes to be discussed, namely, the relative roles played by the indigenous stock and the immigrants from outside in furnishing the abundant population of

[2] Kylin, H. "Zur Kenntnis der Entwicklungsgeschichte einiger Phaeophyceen." Lunds Univ. Årsskr.n.f. Avd. 2. 30 (9).

Calanus finmarchicus, which, in some months, is the all-important feature of the plankton round the Scottish coasts and in the North Sea.

A few critical comments must not be taken as reflecting on the value of the data presented in the paper. The main body of the paper is an account of the captures of *Calanus* made on a large number of cruises by means of horizontal hauls with cheese-cloth nets. Though these hauls are presumably comparable *inter se,* no details are given which would allow of their comparison with any other series, or even with the hauls recorded in the author's first paper; but as an account of vertical hauls made on the same stations is promised in a future paper, it is to be hoped that some standard of correlation will then be supplied. From the figures now given we see that the numbers of *Calanus* in the Faroe-Shetland area are enormously greater than those in the North Sea and to the northwest of Scotland, and the author is inclined to the view that it is from this source that the main summer population of the North Sea is derived, carried in by the known influx of Atlantic water. He supports this view by measurements of the adult females. Off the Moray Firth in March, April, and May the modal size was found to increase from 2·7 mm. to 3·4 mm. The latter size corresponded to that of the females taken off the west coast of Scotland in April. A further argument in support of the immigration theory, based on the dictum that when nauplii are more abundant than ova an influx from outside is indicated, does not appear to be conclusive. The same effect might result from a slackening of local egg-laying.

Amongst other points considered is the proportion of males to females at different seasons. In the North Sea the proportion of males rises from a minimum of 3 % in February and March to a maximum in April of over 40 %. There are indications of a secondary maximum in July. In this connexion Dr. Gibbons remarks that the number of males is seldom high enough to ensure the fertilization of the majority of the females, unless several females are fertilized by one male. He seems to have overlooked the possibility that the preponderance of the females may be due merely to their longer life: the males, once fertilization has been accomplished, have no longer any functional claim to survival.

G. P. F.

A. Steuer. "Biologische Sonderuntersuchungen. II. Lief. Die Verbreitung der Copepoden-Gattungen *Sapphirina, Copilia, Miracia, Pleuromamma, Rhincalanus* und *Cephalophanes* im Südatlantischen Ozean." Wiss. Ergebn. deutsch. atlant. Exped. "Meteor" 1925—1927, Bd. XII, Teil II, S. 101—153, 38 Abb. Berlin u. Leipzig, 1937.

In this paper the study, based on the "Meteor" catches, of the South Atlantic Copepoda, which was commenced by Dr. Klevenhusen with a paper on the Genus *Corycaeus,* is continued by Professor Steuer. The genera now considered are a heterogeneous collection, selected for various reasons. They include 29 species and 7 forms and sub-species, full details of the capture of which are given in tabular form, their distribution being summarized in a series of charts.

The "Meteor" collections, as is well known, were made on about 300 stations situated on a series of traverses of the Atlantic between 20° N. and 60° S., covering the ocean with a comprehensive-looking network of stations.

In his introductory remarks the author gives five reasons why such an extensive investigation has fallen short of giving a complete and satisfactory picture of the distribution of the species concerned. These reasons, briefly,

are:— 1. The gaps in the network, which left some wide regions untouched. In this connexion it might be noted that the distance between the stations on the traverses, in many cases, was from 100 to 200 miles, and the traverses themselves about 400 miles apart. 2. The impossibility of taking into account the time of year. 3. The possibility of diurnal migration taking species out of the reach of nets. 4. The small numbers taken of some of the larger species owing to the type of net used being ill adapted to their capture. 5. The imperfections of the closing-net collections.

In spite of these drawbacks a very considerable addition has been made to the little-known oceanic distribution of a number of forms, and in many instances the limiting factors, temperature, phosphate and ocean currents, on which this distribution depends, can be recognized. For instance, the presence of *Pleuromamma robusta* in a narrow belt between 40° and 60° S. is clearly connected with the antarctic and sub-tropical convergences. This species, common in the North Atlantic and in the aforesaid belt, is entirely absent from the rest of the Atlantic south of the equator, except for a few records from the Benguela Current off the African coast and from the Falkland Current to the east of South America. *Rhincalanus gigas*, a typical antarctic form, finds its northern boundary approximately in the same latitude, ca. 40° S., as *Pleuromamma robusta* but extends southwards to the ice. The very few captures of *Rhincalanus nasutus* were confined to a belt along the west coast of Africa. Of *Sapphirina* and *Copilia* the numbers of the individual species were so small that no satisfactory limits could be laid down, but the author offers the generalization that the latter avoid eutrophic waters while the former, like their hosts the Thaliacea, prefer them.

The appendix by Professor H e n t s c h e l shows in graphic form, for the genera *Pleuromamma* and *Rhincalanus* collectively, the distribution along selected traverses between Africa and South America. As these genera are made up of species with widely differing distributions it is not to be expected that any marked uniformity would be apparent. The diagrams, however, seem to suggest an underlying unity.

A point which occurs to one in reading Professor S t e u e r's summary is that we are ignorant of the weight which should be attached to a collection made at an isolated station in an oceanic area. So few comparitive oceanic collections have been made that we cannot say whether such a station represents the conditions over a wide extent or whether its fauna is merely that of its own immediate neighbourhood.

G. P. F.

R. S. Wimpenny. "The Distribution, Breeding and Feeding of some important Plankton Organisms of the South-West North Sea in 1934. Part 1. *Calanus finmarchicus* (Gunn), *Sagitta setosa* (J. Müller), and *Sagitta elegans* (Verrill)." Min. of Agric. and Fish., Fish. Invest., Ser. II, Vol. XV, No. 3, 1936. pp. 56, 24 figs. London, 1937.

The basis of this paper is a series of Hensen-net hauls on a line of six stations, 12½ miles apart ENE. of Flamborough Head, made at monthly intervals, with only three months missing, between June 1932 and December 1934. These stations were supplemented by more extensive cruises over a large part of the North Sea in June and October 1934.

The three above-named species were selected for detailed consideration, and each has been examined from almost every point of view, numbers, sizes, development and maturity stages, distribution and numbers feeding.

The annual cycle of *Calanus finmarchicus* is traced from its winter resting

condition in stage V through its subsequent changes. The assumption of the adult form is followed early in the year by an abortive breeding, sufficient, however, to give rise to the parents of the heavy concentrations met with in May and June, and these in turn reproduce themselves at the time of the autumn diatom maximum. The author is satisfied that the evidence shows that the species in the North Sea has only three broods each year, thus falling into line with the conditions found in the Clyde and the English Channel.

For *Sagitta setosa*, the low-salinity species, only two breeding periods have been identified, in April and July, the April brood going through its life cycle in three months as compared with the nine months allotted to the July brood. The breeding periods of *Sagitta elegans*, which comes in from the north with oceanic water, are more obscure, but three such are tentatively suggested, one less than the number found off Plymouth.

It was found possible to distinguish by external examination between feeding and non-feeding specimens of both *Calanus* and *Sagitta*, and the proportions of individuals feeding at different times have been tabulated for each species and certain relationships have been established between the numbers feeding and the amount of diatom plankton present. In *Calanus* there is a falling off in the proportion of feeders as the animal approaches maturity.

There is an interesting discussion, in which the data are rather hinted at than actually quoted, of the part played by the diatom concentrations in the North Sea. It is suggested that these patches are actually breeding grounds, rather than areas deserted by zooplankton, and suggestions are made how this view may be reconciled with the observations on which Hardy's hypothesis of "animal exclusion" is based. May we hope that Mr. Wimpenny will give us further details of the occurrence of those larval forms which are undoubtedly in evidence under such conditions.

The only serious criticism that one can make of the paper has already been anticipated by the author when he opens with the proviso that the line of stations under discussion is being slowly and constantly invaded by water masses coming from the north, although for the purposes of argument it is treated of as being in a closed area. As showing the need of keeping this fact constantly in mind, we may instance the chart given of the distribution of *Calanus* ova during the extended cruises in October 1934. This shows moderate concentrations of ova lying both north and south of the Flamborough line, though none were taken on any of the six stations on the line itself.

The paper, as might be expected from one of the publications of the Ministry of Agriculture and Fisheries, is very fully documented and adequately furnished with charts and diagrams.

G. P. F.

Cl. Künne. "Über die Verbreitung der Leitformen des Grossplanktons in der südlichen Nordsee im Winter." Ber. Deutsch. Wiss. Komm. Meeresf., N.F., Bd. VIII, H. 3, S. 131—164, 9 Abb., 4 Beil. Stuttgart, 1937.

Dr. Künne here extends his work into the distribution of the macroplankton "Indicator" species in the Southern North Sea. After a brief summary on the conception of the term "Indicator" species and its use by earlier and contemporary writers, he discusses the value of the concept, reviewing particularly the relative merits of the micro- and macroplankton

Indicators. Examples are given showing how the study of such species may be applied to the problems of the distribution of herring larvae and bottom forms amongst other matters.

The material here described was obtained from a series of seven cruises carried out by three vessels between October, 1934, and February, 1936, in an area broadly corresponding to that part of the North Sea south of Lat. 55°10′N. Surface salinity and temperature observations were taken at all stations and on one of the vessels a complete series of such samples were taken.

The area investigated contains water masses derived from four different regions and each is shown to have its peculiar Indicator species. (1) Northern water (oceanic): indicated amongst other forms by the following relatively abundant species, *Aglantha digitalis rosea, Nyctiphanes couchi, Themisto abyssorum* (*Parathemisto oblivia*), *Limacina retroversa* and *Sagitta elegans elegans.* In addition *Tima bairdi, Cosmetira megalotis, Agalma elegans, Thysanoessa gregaria, Clione limacina, Luidia sarsi* and *Oikopleura labradoriensis* were found in smaller numbers, whilst in March, 1937, four other species of Euphausians were found, *Thysanoessa raschi, Th. inermis, Nematoscelis megalops* and *Meganyctiphanes norvegica.* These may all enter the area from the north-west, but a few are also to be found in the Channel under certain conditions and of these *N. couchi* and *Th. abyssorum* may enter the North Sea from the south with the Channel water: when mixing has occurred forms from the north and the south may be collected together in the same haul. (2) Channel water: Indicators more peculiar to the Channel water are *Turritopsis polycirrha, Gossea corynetes* and *Lammelaria perspicua,* the last two indicating the water which lies more northerly in the Channel and the former the more neritic water hugging the French coast. After entering the Southern North Sea these are intermixed. (3) Flemmish coastal water: indicated by the presence of *Clytia* (*Campanularia*) *pelagica.* (4) The other coastal waters of the area show no Indicators of value with the exception of *Sarsia tubulosa* to be found in late winter and early spring in the waters off the German coast.

The distribution and inter-relationships of the Indicator species are shown in detail by means of a chart for each cruise; seasonal changes in position and the extent of mixing of the forms are found to occur and these are in turn bound up with the changes in strength and direction of the appropriate currents. Some of the striking changes found will be of particular interest in view of the other work in progress and they should be of great value to other workers in the area during this period and in later years. Whilst the Indicator concept is one which should be used only with careful regard to its necessary limitations, this and similar publications show clearly the uses to which it may be put. It might be, however, that in this paper further information regarding the numbers of the different species obtained at the various stations and in different seasons might have been a useful addition. The work of Russell, for example, has shown how a knowledge of the fluctuations of such numbers may also be of value in the application of the concept.

C. E. Lucas.

W. Erdmann. "Ein neues Planktongerät für Horizontalfänge in verschiedenen Tiefen und seine Bedeutung für die praktische Fischerei." Ber. Deutsch. Wiss. Komm. Meeresf., N.F., Bd. VIII, H. 3, S. 165—179, 18 Abb. Stuttgart, 1937.

In 1930 Professor A. C. Hardy and his staff began their investigations into the ecology of the drift-caught herring using the Plankton Indicator as a sampling instrument. Dr. W. Erdmann describes briefly in this paper the old and the new forms of the Indicator, and compares them with older but similar types of apparatus, the Apstein Planktonröhre and Zacharias's Planktonseiher "Etmophor". Following the results obtained with the Hardy Indicator in the English and Scottish drift-net fisheries, Dr. Erdmann was commissioned by Professor Schnakenbeck to investigate the possibilities of its use in the German trawl-fishery of 1934. Subsequent dissatisfaction with its performance at the depths required in this fishery led to the design of a much modified form of apparatus, the description of which forms the bulk of this paper.

The chief criticisms were to the effect that (1) the weighted paravane of the Hardy Indicator was too limited for the purposes of the trawl fishery, a towing line of 200-500 metres being required to reach the normal trawl depths, and that as a result the time taken over a single tow was unduly long; (2) the machine possessed no opening and closing mechanism whereby the collection of plankton might be limited to the required depth (near the bottom) at which the fishing is proceeding. The point is also made that whilst fundamentally each of Hardy's Indicators is similar to the Planktonröhre, the introduction into the later model of "Steuerflächen" (tail-fin assembly) had not significantly improved on the earlier pattern. The suggested defects are considered to be important equally for the scientific uses of the Indicator as well as for its more commercial application.

The new machine is again essentially based on the Apstein model, but it has significant additions which distinguish it from the Hardy model. It consists of a 640 mm. tube of width 120 mm., torpedo shaped, with openings fore and aft of 45 mm. diameter. For depth control there is a new mechanism comprising a vertical fin *below* the cylinder (when towing) on which is mounted an adjustable side plane at each side. The towing depth is controlled by the setting of these planes (three alternative positions for "tief", "mittel" and "flach"), the weight of the machine, the length of the towing lines and the speeds of the ship and the currents. A second important modification is seen in the closing mechanism consisting of a sprung "lid" for the anterior opening, the lid being opened and closed by an ingenious but rather complex system of towing lines and a specially designed release mechanism. The machine descends with the lid closed and at the required depth a messenger striking on the double release gear releases a towing line, 1, the towing strain then going onto another line, 2, and so automatically opening the lid. After fishing, a second messenger releases line 2 (and also 1 which is looped to 2) and the towing strain is now taken up by a third line which, being attached to a projection of the lid, closes the latter and at the same time inverts the whole machine with the result that the lateral planes now direct the machine towards the surface instead of bottomwards (the work of hauling in being thereby considerably lessened). Additional modifications include a new method of attaching the collecting silk and the provision of a protractor and pendulum system (with table of values) for estimating towing depths.

Dr. Erdmann claims that these modifications have overcome the suggested defects in the Hardy Indicator, and in the future he hopes that

it will be possible to use it for the same commercial purposes of locating shoals of herring by means of positive and negative indications ensuring at the same time maximum yields and economies in time and labour. He sees in the future use of coloured charts a possible means of aiding fishermen to distinguish different types of plankton whilst on the disc. On some of these points — the colours of plankton and the relations between the herring in its migrations and the movements of the plankton — the necessity of further research is emphasized and it is in questions such as the latter that he feels that the more scientific value of the instrument will lie.

In principle, the value of the modifications made in the new machine is undeniable and in practice it seems probable that E r d m a n n's vertical fin system should be of value in permitting sampling at much greater depths than can be obtained when towing the Hardy Indicator. Whilst, however, he has found the closing mechanism to be workable (the machine requires the work of two men) it appears to be very complicated for use by fishermen in the practical fishery. Experience has shown that the simplest possible apparatus can occasionally be inconvenient to work under the conditions which are to be met with there. The release mechanism would undoubtedly appear to add serious complications in comparison with the simpler working of the Indicator. It seems necessary to make clear that the Hardy Indicator in its present form was designed essentially for use in the drift-net fishery and also that the use of an indicator in the trawl fishery for herring has been considered by H a r d y, preliminary trawl tests having been made both with the large and small indicators in 1933—36. Whilst the whole of the material has not yet been worked up, brief reference to this work has been made in H a r d y's paper (Journ. Mar. Biol. Assoc. N.S., Vol. XXI, No. 1, p. 157) and elsewhere. In this work samples were obtained both from the surface layers and, by means of modified indicators attached to the trawl itself, near the bottom. Colour and photographic charts have been in use in the commercial application of the Hardy Indicator for several years and in this paper reference will be found to their use together with some discussion of their limitations.

C. E. Lucas.

F. Gudmundsson. "Das Oberflächennetzplankton der isländischen Küstengewässer." Ber. Deutsch. Wiss. Komm. f. Meeresf., N.F., Bd. VIII, H. 4, S. 220—268, 15 Abb. Stuttgart, 1937.

Die Arbeit enthält die Ergebnisse einer quantitativ-qualitativen Untersuchung des Oberflächenplanktons der isländischen Küstengewässer, das 1933 auf einer Teilbefahrung im August und auf einer Rundfahrt um Island im September gesammelt wurde. Zur Untersuchung gelangten jedesmal 50 Liter, die unmittelbar von der Oberfläche geschöpft und durch ein Netz aus feinster Seidengaze filtriert wurden.

Qualitativ lässt sich das Plankton der isländischen Gewässer in folgende drei biologische Gruppen einteilen:— (a) temperiert-atlantische Arten, die nur oder fast nur im Bereiche des warmen, atlantischen Wassers im Süden und Westen vorkommen; (b) boreale Arten, die an der ganzen Küste anzutreffen sind; (c) arktische Arten, die nur im kalten Wasser im Norden und Osten oder nur im Osten gefunden werden.

Die quantitative Seite der Arbeit von G u d m u n d s s o n wird in einem Artikel des Referenten in diesem Heft behandelt. Es wird darum hier nicht darauf eingegangen.

E. Steemann Nielsen.

E. Hentschel. "Zur quantitativen Planktonmethodik." Kieler Meeresf., B. I, H. 2, S. 322—326. Kiel, 1937.

Von verschiedener Seite — Steemann Nielsen, Schmidt-Ries — ist in den letzten Jahren gezeigt worden, dass die Zentrifugenmethode in der quantitativen Planktonforschung oft grosse Fehler aufweist. Bei diesen Untersuchungen wurde jedoch fixiertes Plankton benutzt. Hentschel seinerseits hat lebendes Plankton benutzt und behauptet, dass bei diesem der Verlust bei dem Zentrifugieren gering ist. Dies mag richtig sein. Die theoretischen Auseinandersetzungen Hentschels genügen jedoch nicht; man muss hoffen, dass diese Hypothese noch durch Experimente geprüft wird.

Als Standardmethode bei quantitativen Planktonuntersuchungen schlägt Hentschel jetzt eine neue Methode vor. Eine bestimmte Menge Oberflächenwasser wird durch ein Sieb aus Phosphorbronzegaze filtriert. Die quantitative Seite dieser Methode wird in einem Artikel des Referenten in diesem Heft behandelt und wird darum hier nicht weiter besprochen.

E. Steemann Nielsen.

E. Hentschel. "Über den Ursprung der Heringsnahrung im Norden von Island." Ber. Deutch. Wiss. Komm. f. Meeresf., N.F., Bd. VIII, H. 4, S. 201—219, 5 Fig. Stuttgart, 1937.

Auf Grund sowohl von Magenuntersuchungen von Heringen, die im Juli—August 1936 an der Nordküste Islands gefangen wurden, wie auch von Bestimmungen des Copepodengehalts in 5-l. Oberflächenproben aus demselben Gebiet, sucht Hentschel zu zeigen, dass nur ein kleiner Teil der nordisländischen Calanusbevölkerung von Süden her kommt; sie spielt nur im äussersten Westen eine entscheidende Rolle. Die Hauptmasse kommt mit dem Polarstrom von Norden und breitet sich längs der Nordküste ostwärts vorschreitend aus. Die Euphausidenbevölkerung aber ist im Gebiet beheimatet. Diese sehr interessante Theorie wird nicht durch das spärliche Material Hentschels überzeugend bewiesen, wie er auch ausdrücklich betont; sie ist aber im höchsten Masse der Beachtung und Prüfung wert.

Nur eins mag in der Theorie nach Meinung des Referenten vielleicht nicht ganz mit den wirklichen Verhältnissen stimmen, nämlich dass die Euphausidenbevölkerung des Gebiets endogen ist. Vielleicht kann das für einen kleineren Teil der Euphausiden zutreffen. Die Hauptmasse der Euphausiden, die, wie Hentschel zeigt, im Gebiet bei der Nordostecke der Insel angetroffen wird, stammt wohl aus der Norwegischen See, nördlich von Island. Gerade hier ist fast immer eine kräftige Zufuhr von arktischem Wasser von Norden zu beobachten. Ferner haben die Euphausiden meistens ihre Hauptverbreitung in ozeanischem Wasser.

Es ist zu hoffen, dass die Zooplanktonverhältnisse an der Nordküste Islands in den nächsten Jahren weiteren Untersuchungen unterworfen werden. Für die wertvolle Heringsfischerei hier sind solche Untersuchungen von grosser Bedeutung.

E. Steemann Nielsen.

J. A. Lovern. "Fat Metabolism in Fishes. VI. The Fats of some Plankton Crustacea." Biochem. Journ., Vol. XXIX, No. 4, Pt. I, pp. 847. London, 1935.

Having found that the fats from freshwater fish differ as a whole from those of marine species, the author is at pains to find whether these differences persist in the zooplanktonic food of fish. To this end he has

investigated one marine species, *Calanus finmarchicus* taken from Loch Sunart in May 1933, and three freshwater species, *Cyclops strenuus* from a pond near Aberdeen, *Daphnia galeata* from Loch Lochy, Inverness-shire, and *Diaptomus gracilis* from Loch Ness.

The fats were obtained by desiccating with anhydrous sodium sulphate and extracting with ether.

It was found that all the fats contained large amounts of unsaponifiable matter whose appearance suggested the presence of wax alcohols. A table showing the percentage weight of the different fatty acids is given, in which it appears that the "fish oil" fatty acids (palmitoleic, C_{20} etc.) are present in all. There is, however, an increased proportion of C_{16} and C_{18} unsaturated acids and decreased C_{20} and C_{22} acids in the freshwater compared with the marine species.

Lovern has already found this difference to obtain between freshwater and marine fishes and suggests that a simple ingestion of zooplankton fat largely unchanged in composition would account for the special difference in the composition of marine and freshwater fish fats. The author concludes by pointing out that the zooplankton fats may be decided by the types of fat in their plant food, and that it is really the salinity which affects the plant and causes the different classes of fats. While he adds that experiments in progress suggest that in crustacea the ingested vegetable fat is deposited mainly unchanged, it must be noted that in his more recent published work he has found the distinction between fats from freshwater and marine organisms not to hold in the case of plants.

It is hoped that Mr. Lovern will be able to investigate the fat composition of more marine zooplankton organisms, as at present the class-difference for the fat composition of marine zooplankton depends upon the single species *Calanus finmarchicus*.

R. S. W.

W. F. Thompson. "Theory of the Effect of Fishing on the Stock of Halibut." Rep. Internat. Fish. Comm., No. 12, pp. 22, 6 figs. Seattle, Wash., 1937.

Dr. Thompson holds that a simple statement of the theory of regulated fishing is necessary because no programme of control can be carried out unless as many as possible of the more intelligent and interested men concerned understand it. The method he choses is by tabulation of numerical examples. He deliberately avoids any algebra or much graphical representation, in the hope of thereby being readable by as many people as possible. The result is rather long, about 16 pages. It undoubtedly could convey all that is essential to an intelligent and patient layman. This is valuable, and is no mean achievement.

Scientists and students who wish to understand the theory may be interested in the various forms the same argument has taken, as propounded by other workers. It is possible to pick out short statements from each. These are self-explanatory and not at all difficult.

Baranoff showed graphs of age- or length-frequency, under various rates of fishing. The area under such graphs is the stock. Increase the rate of fishing and you decrease the area, but take a greater percentage of it. At some intermediate rate the product of decreasing area and increasing percentage would have a maximum.

Hjort, Jahn and Ottestad think it likely that growth of a stock of fish growing freely in a given area would follow a sigmoid curve of

population. If put into equilibrium by fishing, the crop would equal the differential of the stock curve. This has a maximum — maximum crop, optimum catch — at the point of inflexion of the main curve.

The reviewer's short statement was that everyone knows there is a most profitable age to harvest any growing crop. Other things being equal the age of the stock, and therefore crop, is controlled by mortality due to fishing. Therefore there is an optimum rate of fishing.

M. G.

E. Ford. "The Nations Sea-Fish Supply." The Buckland Lectures for 1936. pp. 112, 8 figs., 3 pl. Edward Arnold & Co., London, 1937.

Es ist eine wichtige und schwierige Aufgabe des Fischereiforschers, die Menschen, die mit dem Seefisch zu tun haben, vom Fischer bis zum Verbraucher, mit den Ergebnissen seiner Forschung vertraut zu machen: wichtig, weil seine Arbeit nur dann fruchtbar wird, wenn ihm dies gelingt; schwierig, weil es gilt, die Ergebnisse umfangreicher Forschungen und keineswegs einfacher Gedankengänge kurz, klar und einleuchtend, doch allen möglichen Einwendungen gerecht werdend, darzustellen. Fords Buckland Lectures für 1936 bewältigen diese Aufgabe in vorbildlicher Weise.

Ford will zeigen, wie notwendig die von der Internationalen Meeresforschung geforderten Massnahmen zum Schutze untermassiger Nutzfische sind. Im ersten Teil seiner Schrift geht er von der Notlage der Fischereiindustrie in den vereinigten Königreichen aus, die das Eingreifen des Staates nötig machten. Nicht nur die Weltwirtschaftskrise, nicht nur die Konkurrenz anderer Lebensmittel war daran schuld, sondern auch eine fehlerhafte Einstellung der Fischerei, die danach strebte, alles zu fangen, was gefangen werden kann, statt das zu fangen, dessen man vor allem bedurfte: grosse Fische guter Qualität. Die Staaten müssen nun, beraten von ihrer Fischereiforschung und durch das Mittel ihrer Fischereiverwaltung, den Weg zu einer vernunftgemässen Ausnutzung der Seefischbestände führen, den die Fischerei nicht fand. Eine neue Epoche ist angebrochen.

Das zweite Kapitel legt die Massnahmen dar, die die britische Verordnung wie die Londoner internationale Vereinbarung vorsieht. In sorgsam klarem Aufbau werden uns die wissenschaftlich-technischen Grundlagen unterbreitet, angefangen von dem Beweis, dass die Fische lebend durch die Steert-Maschen des Schleppnetzes entkommen können, bis zu den Feststellungen über die Selektion der Maschen und den Erfahrungen, die bei den grossen Vergleichsfischerien von Fischdampfern mit Netzen verschiedener Maschenweite gewonnen wurden. All die Schwierigkeiten, die sich z. B. aus der verschiedenen Gestalt und Grenze der Marktfähigkeit der Fischarten erheben und die individuelle Regelungen für einzelne Fischereien wünschenswert machen, werden nicht verschwiegen, ohne dass die Überzeugung von der Zweckmässigkeit der Massnahmen erschüttert wird.

Unter der einprägsamen Überschrift "ein lebender Rohstoff" wird der Leser im dritten Teil in die Wirkungsweise der biologischen Faktoren eingeführt, die den Ertrag der Fischerei bestimmen. Wir hören von Nahrung und Wachstum, von der Fortpflanzung und den Schwankungen der Nachwuchsmenge, der natürlichen Sterblichkeit und der Zehrung durch die Fischerei, die einen Fisch eben nur einmal fangen kann: entweder als kleinen, jungen, unreifen, oder als älteren, grossen, reifen Fisch. So lernen wir erkennen, dass die Fischerei, die einen möglichst hohen Ertrag erzielen will, eine wohlüberlegte Auswahl unter den Fischen treffen, nicht aber unterschiedslos möglichst viele umbringen muss.

Sicherlich wird die Schrift in ihrer Klarheit und Ehrlichkeit das Verständnis für die Fischereiforschung und ihre Ergebnisse in weiten Kreisen verbreiten helfen.

Bückmann.

Ed. le Danois, L. Beaugé, G. Belloc, M. Boury, P. Desbrosses, J. le Gall, L. Lambert and D. Rémy. "Die französische Seefischerei." Handb. Seefisch. Nordeuropas. Bd. VII, H. 1, S. 180, 136 Abb., XVIII Taf. Herausg. v. H. Lübbert und E. Ehrenbaum. E. Schweitzerbart'sche Verlagsbuchhandlung. Stuttgart, 1937.

This valuable work, with its wealth of detail and precise information, forms a most important contribution to the much appreciated handbook of North European fisheries. The great number of collaborators, no less than eight, turns out to be more of an advantage than might appear at the outset, as each deals with the subject most familiar to himself.

To the Northerner, accustomed as he is to the leaden sky and stormy and sombre seas of his everyday habitat, it is somewhat of a relief to turn to those brighter, sun-favoured regions, which his memory, perhaps out of a vague reminiscence of Viking life, paints with a mystic and romantic hue. This may apply even to the fishermen, howsoever rough as they often are, as far as they ply their craft in sight of the lovely shores of France.

The book begins with some statistical data, concerning the present scope of the French fisheries, and continues with their organization (also that of scientific research), followed by a description of the various branches of the fisheries.

It appears, to open with the trawl fisheries, that the present trawl, culminating in its more perfected shape of the Vigneron-Dahl net, has had many precursors in France, like anywhere else. As to France, it is worth mentioning that in such groping experiments as the available means allows, one recognizes a method which was, only a few years since, still in use locally in the country of the present writer: two fishing vessels towing a seine-like net between them ("gangui boeuf", Spanish: "pareja"). In later years one of these vessels was replaced, in case of a strong current, by a "bourset", a sail, spread out under water, held open at the upper leech by a boom, and kept floating by a wooden buoy. Such a floating body was likewise attached to the bow of the fishing vessel.

The application of steam power led, as everywhere, to various stages of development, *via* drag and beam-trawl to otter-trawl and V.D.net. The present steam trawlers are powerful vessels, with a steel hull of 40—50 m. length, a "brut" tonnage of 200—450 register tons, and engines of 300—750 H.P. The latest inventions are all turned to account: wireless (also used for taking bearings), echo-sounding gear, etc. The kings among these trawlers, going a-fishing to Newfoundland and Greenland are fitted with freezing plants and apparatus for the manufacture of fish meal and extraction of liver oils. Diesel motors proved, however, to be still more economical than steam power in the long run, especially for the "Grande Pêche", since '28.

Herring are trawled with a narrow-meshed net without wings, with a vertical kite in the middle of the head-rope to which glass floats are attached. The principal localities are the Smalls and the waters to the south of Iceland; since 1927 also the North Sea.

Formerly drift-net fishing was carried out by sailing luggers (which were the model for similar sailing craft abroad, as in Holland and Germany),

but these have practically disappeared in the last ten years. They have been replaced by steam drifters, fitted for both drift-net and trawl fishing, hailing especially from Boulogne and Fécamp. The whole set of nets is composed of 250—300 cotton nets, and is used in the Dutch manner. Herring are not gutted, but preserved in salt and ice. Another pelagic fish, the mackerel, is usually fished by smaller vessels; this fishery is mainly carried out, during the summer season, with drift-nets, wider meshed and less high than those for herring, and set out in the Scotch way. Mackerel are also caught from sailing vessels with trailing lines, kept out on cross booms, and by handlines.

A kind of trailing net is used in the sardine fishery, especially on the shores of Britanny. The vessels used are driven by motor power, but a kind of dory is the real fishing boat. To attract the fish, bait (of several kinds, salted cod roe seems to be preferred) is strewn. Older fishes, pilchards, are caught in special drift-nets.

Fishing for tunny is carried out by sailing vessels, like sloops, with trailing lines, fastened to cross booms. The hooks are baited with Indian cornstraw, horsehairs and small red rags. The white tunny (*Thynnus alalonga*, germon) is the chief game.

The Grande Pêche, which involves long voyages to Iceland, Greenland and the banks of Newfoundland, has, with its sturdy, but somewhat uncomfortable and quaint sailing vessels, a time-honoured claim to world fame. Such vessels are still fitted out in some ports, cutters at Gravelines and schooners at Paimpol; both have fore-and-aft sails, but the latter type is peculiar in being square-rigged on the foremast, where she carries a top-gallant sail. These vessels, with a motor as auxiliary power, fish near Iceland and catch cod by handline, but no dories are used.

A similar but even more antiquated feature is possessed by the three-masted schooners fishing on the Grand Banks. These schooners are in some cases entirely square-rigged on the fore-mast; others have fore-and-aft sails on all three masts. The home port is St. Malo. Fishing is carried out with a set of dories, each of which accommodates (if spending a cold night on such a craft may be so called) two men, who fish with a great many handlines, generally baited with whelks (bulots) or squids.

The real monarchs of this Grand-Banks fishery, however, are large and powerful motor vessels. Among them we find the largest trawlers of the world (70—76 m. long, engine 1000—1200 H.P.), such as "Marcelle" and "Jutland". The V.D. net is universally used, and the hard bottom necessitates the use of bobbins on the ground rope. As might perhaps be expected, however, the achievements of these super-trawlers are often disappointing.

Since the treaty of Utrecht (1713), which put an end to the war of the Spanish Succession, France has the exclusive right of fishing on the west and north coast of Newfoundland, but since the fishery on the Banks yielded better results, this right is generally not made use of.

The fishing ports of France are treated regionally. It is generally known that the largest ports are those of Boulogne, Fécamp, Lorient, La Rochelle, Bordeaux and Marseilles.

Each of them, of course, specializes in some way or another. Some of them are better fitted for cod fishery on the high seas; others, like Boulogne, Dieppe, Lorient, for trawl fishery; again others, like Douarnenez, Concarneau, Sables d'Olonne, Arcachon and Marseilles, for coastal fishery or shellfish culture. A special chapter is devoted to the preparation of fish (salting, smoking, tinning).

Most important is the artificial rearing of shellfish, notably that of oysters. Natural or "wild" banks are now mostly depleted. The swarming fry of oysters are caught either by pantiles or by dead cockle-shells, and the rearing of the brood is carried on in parks. Along the whole Atlantic coast of France oysters and mussels are being reared, notably so in Britanny. The culture of the latter, at least in places where the difference in tides is very large, as in the middle of the Atlantic coast and at the mouth of the Vilaine, is being done by means of huge piles ("bouchots"); sometimes, however, on flat areas ("à plat"), as at Le Croisic.

Other species of shellfish are also reared locally, as *Cardium edule, Tapes decussatus, Littorina littorea.* There is also a fishery for clam mussels (various species of *Pecten*).

Altogether this is a most useful and highly informatory volume, and the editors are to be greatly congratulated on its publication.

J. J. T.

Ad. S. Jensen. "The Greenland Halibut (*Reinhardtius hippoglossoides* (Walb.)). Its Development and Migrations." Mém. Acad. Roy. Sci. Lettres Danemark, Sect. Sci., Sér. 9, t. VI, No. 4, pp. 32, 4 pls., 1 text-fig., 6 charts. København, 1935.

The Greenland, Blue or Lesser Halibut, known to the Danes as "Hellefisk" and to the Greenlanders as "Kaleralik", is not only a species of considerable economic importance, but from a biological point of view is perhaps one of the most interesting of the northern flatfishes. It is less markedly asymmetrical than most other members of the order Heterosomata, the two sides of the body being nearly equally muscular, and the left (or blind) side being almost as heavily pigmented as the right. Further, the eye of the left side lies nearly on the edge of the head, being well separated from its fellow of the right side. A study of the life history of the species, and especially of the development of the larvae and young, indicates that these conditions are secondary, and are connected with the fact that the Greenland Halibut frequently leaves the bottom and comes up into the intermediate layers of water in pursuit of prey.

The Greenland Halibut has a wide distribution in the arctic parts of the Atlantic, and reaches a weight of 5 to 10 kg. In this important paper the author summarizes the results obtained from several investigations made over a number of years in west Greenland waters, and gives us for the first time a valuable and comprehensive account of its development and migrations. The Greenland fishery is mainly carried on in the fjords and bays on the west coast, but it is shown that spawning takes place at some considerable distance away, "in the deep parts of the Davis Strait, south of the submarine ridge, which extends about 67° N.L. from Greenland over to America." The eggs and early larvae are bathypelagic, but the latter soon enter the surface layers and gradually move either inwards towards the coasts of south Greenland or northwards towards north Greenland. At a length of about 70 mm. they undergo a metamorphosis similar to that found in other flatfishes, the symmetrical larva becoming transformed into the asymmetrical bottom-living young, with the upper surface pigmented and the lower white. Subsequently, however, the left or lower side becomes pigmented, and is eventually almost as dark and muscular as the right side.

J. R. N.

W. A. Clemens, J. L. Hart and G. V. Wilby. "Analysis of Stomach Contents of Fur Seals taken off the West Coast of Vancouver Island in April and May, 1935." Dep. Fisheries, Ottawa, pp. 20. Ottawa, 1936.

Every year large numbers of fur seals, *Callorhinus alascanus*, appear off the west coast of Vancouver Island, British Columbia. They are believed to be on a breeding migration to the Pribilov Islands. In an effort towards determining the part played by these migrating seals in the economy of the sea off the west Canadian coast the authors examined the stomach contents of 593 seals killed off the southern part of Vancouver Island in 1935. Most of the seals were captured between five and thirty miles offshore. The inshore limit is believed to correspond with the distribution of the seals at the time of the year when hunting was carried out (March—June) but the outer limit is without significance.

Of the 593 stomachs obtained 400 were empty. Examination of the contents of the 193 stomachs which contained food led the investigators to the not surprising but nevertheless important conclusion that the seals feed mainly on fish and that they take as food whatever fishes are most readily available to them. Animals taken after about the middle of May contained salmon significantly more often and herring significantly less often than those captured earlier in the season. This agrees with what was known of the relative abundance of these fishes at those times. Numerous other organisms, including additional species of fish, squids, and crustaceans, were also eaten by the seals. The data are carefully tabulated and furnish undoubted evidence of the consumption of considerable amounts of commercial fishes by the seals. But accurate estimates of the actual quantities could not be made because of lack of knowledge of the width of the migration belt, the time taken by the seals in passing the British Columbian coast, the numbers present throughout the migration period, their feeding habits and rate of digestion. The authors have succeeded, however, in making a very useful preliminary survey and have put forward useful recommendations for further researches which, if carried out, will undoubtedly yield information of great interest and value.

G. A. S.

D. P. Wilson. "The Habits of the Angler-fish, *Lophius piscatorius* L., in the Plymouth Aquarium." Journ. Mar. Biol. Assoc., N.S., Vol. XXI, No. 2, pp. 477—496, 2 figs., 1 pl. Plymouth, 1937.

The paper describes interesting first-hand observations on a number of angler-fishes kept alive in the Plymouth aquarium for varying periods of time. Five survived for a few weeks only, but five others, of an average length when captured of 9½ inches, lived for several months. These provide useful information on growth-rates under aquarium conditions with an apparent sufficiency of food. One survived for 11 months and grew 7¾ inches in this time. Four others lived for between 2½ and 5 months, making growths of between 1¼ and 2½ inches. Wilson gives the average growth of his specimens as being at a rate of 8½ inches a year. Fulton has previously assessed the growth-rate in nature for fish of a size roughly comparable with those of Wilson to be a little over 6 inches a year. Hand feeding with dead fish of various species was adopted for the first few weeks. Later the fishes took to capturing living prey with the use of the lure. The paper deals at some length with the reactions of the angler

fishes to their prey and their mode of capturing it. It is stated that they showed strongly marked individual characteristics. Fishes intended for food, if not captured, learn to avoid the angler-fishes and to respect the dangers of the lure. The notes on the types of fishes taken in the aquarium agree roughly with the conclusions reached by Fulton, Todd (who is not mentioned), and others on the species captured in nature. The summary of Fulton's remarks (p. 493) is rather misleading. Fulton does *not* say "nearly half the stomachs were empty and were 'shrunken and collapsed' ...." but "48·2 per cent. were found to be empty, and *in many instances* the stomach was shrunken and collapsed, ..."

Whilst Mr. Wilson confirms, and to some extent repeats, much that is already known and well described, he fills in many gaps in our knowledge of these curious fishes and is to be congratulated on his success in keeping them alive, notoriously difficult as they are, and upon his excellent photograph of an angler adapted to its background.

H. O. Bull.

E. Hentschel. "Naturgeschichte der nordatlantischen Wale und Robben." Handb. Seefisch. Nordeuropas. Bd. III, H. 1, S. 1—54, 60 Abb., 10 Taf. Herausg. v. H. Lübbert und E. Ehrenbaum. E. Schweizerbart'sche Verlagsbuchhandlung. Stuttgart, 1937.

In this extremely useful paper the author, as he explains in the preface, sets out to describe in handbook form the appearance and natural history of the North Atlantic seals and whales excluding only some very rare forms of the latter.

Following a preliminary outline of the more outstanding features of the external and internal anatomy is a short section on the habits of the animals.

It is difficult to see why the author, in the systematic arrangement of the Cetacea recognizes the family Delphinapteridae whilst he includes the Bottle-nosed Whale, *Hyperoodon rostratus*, in the family Physeteridae. The family Ziphiidae should be recognized even although, with the exception of *Hyperoodon*, the species included in it are very rarely occurring animals. But these, however, are points of theoretical interest which do not materially affect the main purpose of the work.

The description of individual species is prefaced by a list of the common names used in different countries, surely a benefit, in certain of the Cetacea at any rate, where because of nomenclatorial alterations it is almost essential nowadays to use common name with proper name to know to what animal reference is being made.

Vertebral formula and total length are stated for each species, and coloration, distribution, habits, food, reproduction and economic importance are considered. A scale diagram gives a good impression of the comparative size of the Cetaceans referred to and in addition there are outline drawings accompanying the description of each species besides a number of photographs of the animals themselves.

The seven species of North Atlantic seals are also adequately described and figured.

This handbook is a welcome addition to the literature concerning Cetaceans and Pinnipedes and should certainly fulfil the purpose for which it has been written.

F. C. F.

J. R. Norman and F. C. Fraser. "Giant Fishes, Whales and Dolphins." pp. 361, 97 figs., pls. VIII. Putnam and Co., Ltd., London, 1937.

Dieses höchst beachtenswerte Buch ist im September 1937 erschienen. Der Plan dazu kam den Verfassern infolge der zahlreichen Anfragen, welche an ein grosses Institut wie das British Museum regelmässig gelangen und Auskunft wünschen, in Sonderheit über grosse Tiere wie Wale, Delphine und Riesenfische. Namentlich Sportsleute, z. B. Angler, wünschen sich über die Gegenstände ihres Sports zu unterrichten, wie den Thunfisch, Tarpon u. a., aber auch die ständig wachsende Zahl der Ozeanreisenden sucht nach Belehrung und zuverlässiger Bestätigung ihrer eigenen Beobachtungen.

Es lag nahe, solche Wünsche durch eine umfassende und sorgfältige Belehrung in Form einer gut und reich bebilderten Veröffentlichung zu erfüllen, und niemand war berufener, die Durchführung dieser Aufgabe zu übernehmen, als die Verfasser des vorliegenden Werkes in ihren Stellungen am Natural History Museum at South Kensington: J. R. Norman, als Verwalter der Fischsammlungen, bekannt durch zahlreiche Veröffentlichungen auf seinem Spezialgebiet, und F. C. Fraser, der die Walsammlungen des British Museum (Nat. Hist.) betreut und als Mitglied der britischen "Discovery" Expeditionen drei Mal Gelegenheit hatte, in der Antarktis die Wale in ihrer natürlichen Umgebung zu studieren. Diesen beiden hervorragenden Sachkennern gesellt sich als Illustrator Lt.-Col. W. P. C. Tenison, der sich durch seine Mitarbeit an vielen wissenschaftlichen Werken und besonders als Helfer von J. R. Norman einen wohlverdienten Ruf erworben hat.

Die unvergleichlichen Sammlungen des British Museum's und dessen reiche literarische Hilfsmittel boten den Verfassern die beste Unterstützung zur Durchführung ihres Planes.

Das Buch ist in gemeinverständlicher Sprache verfasst und setzt sich, wie der Titel erkennen lässt, aus zwei grossen Abschnitten zusammen, von denen der eine sich mit den Fischen, der andere mit Walen und Delphinen befasst, und in beiden Teilen sind die äussere Erscheinung, der Bau, die Lebensgewohnheiten, die Ernährung und die Art der Fortpflanzung bei den verschiedenen Arten ausführlich behandelt.

Der erzählende Teil ist vervollständigt durch Bezugnahme auf historische und legendäre Berichte mannigfacher Art; Anekdoten und Erfahrungen machen den Gegenstand lebendig und anziehend.

Die Reihe der behandelten Formen beginnt mit den Knorpelfischen, den Haien und Rochen; unter letzteren wird eine ganze Anzahl riesenhafter Arten namhaft gemacht, wie z. B. die Sägefische, Stechrochen, Adlerrochen und die abenteuerlichen Teufelsrochen *Manta* und *Mobula*. Nicht minder zahlreich ist die Menge der grossen Haifischarten, die Erwähnung finden, und es ist auffallend, in wie wenig Fällen hier von einer wirtschaftlichen Verwertung gesprochen werden kann. Wenn indessen die in vielen Meeren verbreiteten Herings- und Makrelenhaie (*Lamna*) als zwar nicht selten aber von keiner grossen ökonomischen Bedeutung bezeichnet werden, so wird man dem, in Ansehung der gewaltigen sich nach vielen Millionen kg. beziffernden Haifischfänge der Norweger, nicht beipflichten können.

Es folgen die Knochenfische und unter ihnen die Weichflosser, bei denen als besonders grosse Formen der Tarpon, die Congeraale, die Muränen und mancherlei seltenere Arten aufgeführt werden, unter denen aber auch einige kleinere Formen wie Hornhechte und Fliegende Fische Erwähnung finden, weil sie von Seereisenden oft beobachtet werden.

Nicht gering ist auch die Zahl der riesenhaften Formen unter den

barschartigen Hartflossern (*Epinephelus*), denen sich die Gelbschwänze (*Seriola*), Coryphaeniden, Adlerfische, Makrelen- und Thunfischartige, Speerfische und Segelfische nebst vielen Verwandten (Schwertfische u. a.), Barracuda, Sonnenfische und endlich grosse Plattfische (Heilbutt) anschliessen.

Den Beschluss bilden, wie schon gesagt, die Wale und Delphine, beide Gruppen in seltener Vollständigkeit, indem nicht nur die häufigen und wirtschaftlich wichtigen, sondern auch die selteneren Arten beschrieben und in vortrefflichen Abbildungen dargestellt sind (vgl. z. B. den Blauwal). Namentlich die neueren Ergebnisse der britischen und norwegischen Untersuchungen über diese Gruppen sind in sehr erschöpfender Weise wiedergegeben.

Das vorliegende Werk ist in seiner Vollständigkeit wohl geeignet, dem interessierten Leser eine grosse Menge einschläglicher und nicht immer leicht auffindbarer Literatur zu ersetzen. Der bescheidene Preis (geb. 15 sh.) macht es verhältnismässig leicht zugänglich.

E. Ehrenbaum.

H. B. Moore. "The Biology of *Purpura lapillus*. I. Shell variation in relation to environment." Journ. Mar. Biol. Assoc., N. S., Vol. XXI, No. 1, pp. 61—90, 11 figs. Plymouth, 1936.

The author points to the suitability of the dogwhelk, *Purpura lapillus*, as a subject for the study of shell-variation in that a free swimming stage is absent and the species is limited to rocks by barriers of sand or deep water, so that a given community is self-contained. It is also stated that the variations found over a wide range of geographical distribution on the North Atlantic European and American seaboards are reproduced in a relatively small region. In such a region, mainly in the south-west of England, samples were collected from 76 localities covering a wide range of environmental conditions and the variations studied in relation to what were considered two primary factors, namely, the degree of exposure to wave-action and diet. Various colours of the shell, shell weight, apical angle, spiral angle, degree of shell thickening, height of shell at cessation of growth, and height at sexual maturity were found to show directly or indirectly various degrees of correlation with diet. The latter is given as consisting of *Mytilus edulis* and one or both of the barnacles, *Chthamalus stellatus* and *Balanus balanoides*. The author's results are possibly somewhat vitiated here, since the rock limpet, *Patella sp.* or varieties, often forms a good proportion of the diet in some localities in Cornwall, e.g., Looe, and the snails *Gibbula* and *Littorina* are also often attacked. It is deduced that an increase of *Mytilus* in the diet tends to produce a fatter shell with a more open spiral, increases the height of the shell at which maturity sets in, but decreases the proportion of mature thick shells. Cessation of shell-growth with concurrent lip-thickening, and of size at which a change in the spiral angle occurs are shown to be dependent upon onset of maturity. These results are of great interest and should be of value in prosecuting further studies. The two colour-types, black-brown and mauve-pink — whose pigments are shown experimentally to be at least largely due to *Mytilus* — are closely correlated in frequency with abundance of *Mytilus* in the diet.

Wave-exposure can be correlated only with one character, that of yellow shells. These are found in all kinds of medium exposures, but rare in the lowest and greatest. Below low water a tendency to gigantism is found in some localities and in others the variety *imbricata*. The abundance of the

large sub-littoral variety in the Thames estuary is apparently not known to the author.

One outstanding discovery in this interesting paper is the change in shape of the *shell* at sexual maturity similar to that found by Russell and Orton in *Patella.*

J. H. Orton.

K. M. White. "Mytilus." Liverpool Mar. Biol. Committee, Memoir XXXI, pp. 117, 10 pl. Liverpool, 1937.

This anatomical study of the common mussel continues the wellknown series of monographs devoted to typical British marine plants and animals of which no adequate account exists in the text-books.

Earlier accounts by de Heide, Sabatier and Purdie were followed in 1902 by List's "Die Mytiliden des Golfes von Neapel" which, however, does not include *Mytilus edulis,* and Field's "Biology and Economic Value of the Sea Mussel" in 1922. As guides to the anatomy of the mussel these publications still left something to be desired, which this monograph has supplied, with its clear and concise instructions for dissection, its well-arranged description, and excellent drawings by which anatomical relationships of constituent organs to the whole animal are particularly well indicated. Sufficient general biological information is included to indicate the position of this species in relation to other lamellibranchs, nor is its economic importance overlooked. An adequate bibliography is included.

In view of the important place which this work will undoubtedly take in literature on shellfish, one statement relating to mussel poisoning is unfortunate, viz., that illness due to the serious (paralytic) form is similar to strychnine poisoning. The author rightly points out that death, if it occurs, is usually due to respiratory paralysis, but the interference with respiration resulting from strychnine poisoning comes, of course, in an entirely different category. The clinical picture is, in fact, quite different. The mechanism of mussel poisoning resembles that of curare poisoning, viz., paralysis of motor nerve endings, while strychnine acts upon the spinal cord, and has actually been suggested as an antidote for curare poisoning and vice versa.

H. P. S.

W. J. M. Menzies. "The Movements of Salmon marked in the Sea. I. The North-west Coast of Scotland in 1936." Fisheries, Scotland, Salmon Fish., 1937, No. 1. Edinburgh, 1937.

The main interest of this report appears to centre on the following features.

The marking station at Loch Inchard is situated further west on the coast of Scotland than any of the previous stations in the period 1913—15 and 1921—22. As Mr. Menzies himself seems to imply this locality is probably situated closer to the ocean feeding grounds, whence the fish come in search of their native rivers. As a probable result of this we may take the fact that whereas the earlier east coast markings showed very few migrations from the Scottish east coast to the north or west, the Loch Inchard experiment in 1936 shows recaptures from the west as well as from the east coast, with a prominent trend north and east.

The migrations shown by this experiment have, as far as I can judge,

a greater similarity to the always fanlike spread in all directions exhibited by the Norwegian results for 1935 and 1936, than appears in any of the earlier Scottish experiments.

In one respect the similarity to the Norwegian results is also striking, a fish having crossed over to the mouth of the Sognefjord, just as numbers of Norwegian fish have lately been proved to migrate from Norway to Scotland. This fish is the first proven case of a fish migrating from Scotland to Norway and also presents the further interest that an examination of its scales, which I was able to forward to Mr. Menzies, proves it at all events to be a fish which cannot have spent its parr life in a river in Scotland.

It is also of great interest to note that this fish was marked with the *large addressed mark* which Mr. Menzies has adopted after the Norwegian experiment. Marked with the ordinary Archer-Landmark tag, the probability is that the fish would have passed unnoticed in Norway.

The percentage of recaptured fish was low, 11·7 %.

Knut Dahl.

A. Hassard. "Two Fish Passes on the River Shannon." Inst. of Civil Engineers of Ireland. pp. 187—208. Dublin, 1937.

Hydraulics and the designing of fish passes are closely related. But a knowledge of hydraulics is not commonly to be found with an equally sound knowledge of fish; nor is the importance of hydraulics as fully realized as it might be among those whose business it is to study the movements of migratory fish. Accordingly, when a civil engineer with experience of the behaviour of salmon is concerned with the devising of the form and dimensions of a fish pass the occasion is of more than ordinary significance.

Mr. Hassard, a past President of the Institution of Civil Engineers of Ireland, has for many years been on the established staff of the Fisheries Branch of the Department of Agriculture of the Irish Free State. His paper on the subject of fish passes he designed at Parteen and Lough Allen in connexion with the Shannon Power Scheme can therefore be regarded as a notable instance of such an occasion.

The pass at Parteen, where the main impouding dam across the Shannon is situated, is of the recognized pool and traverse type, of a total length of 487 ft., consisting of sixteen pools (including three larger resting pools) and providing a mean surface water gradient of approximately 1 in 19 for a total rise of 26 ft. from tail water to top water level.

The pools are 23 ft. long (the resting pools being from twice to three times as long) and from 10 ft. to 13 ft. wide with a depth at stagnant water level of upwards of 3 ft.

For reasons of space and economy in construction the pass is bent acutely on itself in its lower third — one of the resting pools occupying the bend — and it discharges as close as was practicable to the left abutment of the dam below the regulating sluices.

The rise from pool to pool through the notches (which are 3 ft. 4 in. in length) in the traverses at still water level is approximately 1 ft. 8 in. A feature of the traverses is that, instead of being level crested, they are sloped down from the retaining wall to the notch. The designer admits that this did not prove entirely satisfactory in practice, tending as it did to engender a flow at right angles to the stream passing through the notches. To correct the fault the crest of the spur wall, which projected upstream at the junction

of each notch and the corresponding traverse, was enhanced by adding a 9-inch plank.

The supply of water to the pass is governed by an intake sluice at each of the three highest pools. As a result of observation it would appear that the optimum quantity is at the rate of 14 cusecs. This flow — having regard to the size of the river at that point — does not seem large. It would be interesting to know what percentage of the total flow below the regulating sluices at the dam it represents and whether the "lead" it provides at the outlet of the pass can be considered adequate.

The pass, however, appears to have functioned satisfactorily. It was first brought into operation on 27th July 1929 and during 1930 many salmon were observed using it, as many as 1,000 having been counted on one day (18th May) passing up.

At Lough Allen the proposition was of a somewhat different sort. Here there is no actual dam to be negotiated, the obstruction being caused by the shutting down of sluices at the outlet of the lake to pond the water for storage purposes, until a head of approximately 18 ft. above the sluices has been accumulated. In periods of low flows, when storage is impracticable, the sluices will probably remain open and the difference in level of water above and below will be nil.

Mr. Hassard designed a fish pass of a less commonly known type, the feature of which is a series of pools communicating with each other and with the storage and outfall waters by means of submerged orifices. The recognized advantages of this type of pass are elimination of effervescence, appreciable shortening in length in proportion to the total rise and less variation in rate of flow with varying heads.

The problem was to determine the size and number of the pools and orifices required to pass a given flow at a velocity not greater than a settled maximum and at the same time adequate in amount to attract the fish into the pass. The quantity of flow available was at the rate of 36 cusecs and a velocity not exceeding 6 ft. per sec. was deemed advisable. From hydraulic calculations based on these data the pass as recommended consisted of 10 pools, each pool 20 ft. long by 10 ft. wide, and 11 intervening submerged orifices, each orifice 3 ft. by 2 ft. in area with an average head at each orifice (i. e., a difference in water level above and below) of 1 ft. 6 in. At the outlet provision was made for a continuation of the parallel retaining walls into the main stream so as to form a "free pool" through which fish might more readily be disposed to discover the entrance to the pass. To test the design experiments were made with a working model, with results that appeared to be satisfactory.

For various reasons, however, the original design was modified by a reduction in the number (from 10 to 9) and size (from 20 ft. by 10 ft. to 18 ft. by 8 ft. 10 in.) of the pools and in the number (from 11 to 10) and area (from 3 ft. × 2 ft. to 2 ft. 11 in. × 1 ft. 11½ in.) of the orifices. The pools, moreover, were constructed with their longer axes forming the cross walls instead of — as originally planned — coinciding with the parallel retaining walls; and the proposed "free pool" at the outlet was omitted. It is also apparent, from the plan of the pass as ultimately constructed, that there is some irregularity in the size and shape of the pools.

The pass has only recently been completed and it is as yet too soon to be able to express a considered opinion on its satisfactory functioning. From the level at which the orifices have been placed, however, it would at the least seem to be safe to assume that submergence at all times is likely.

T. E. P.-T.

D. A. Webb. "Studies on the Ultimate Composition of Biological Material. Pt. II. Spectrographic Analyses of Marine Invertebrates, with Special References to the Chemical Composition of their Environment." Sci. Proc. Roy. Dublin Soc., N.S., Vol. XXI, No. 47, pp. 505—539. Dublin, 1937.

The constituents considered are boron, silicon, phosphorus, fluorine, and about twenty metals which the work of the past twenty years has shown to occur in animal and vegetable tissues as "trace elements". The ordinary methods of chemical analysis are not usually applicable to this type of work and spectrographic methods have been largely used: the results which have been obtained leave little doubt that these trace elements play important parts in the metabolism of both plants and animals. An exact knowledge of the mineral content of tissues is a necessary preliminary to the study of the function of these elements, and refined and reliable methods of analysis are being worked out to supply it. Ordinary chemical separations are seldom applicable as they are inexact when applied to very small quantities of metals or very dilute solutions. Further, serious errors may occur in processes such as ashing, in the use of some glass and other vessels and, not infrequently, owing to the use of reagents containing impurities.

The method here employed is based on arc spectra produced between silver electrodes and the samples were dried, charred, powdered with an equal weight of "Specpure" ammonium sulphate, the powder being spread over the surface of the lower electrode and the current passed. A Hilger medium-sized quartz spectrograph was used, the range of spectra being from wave-lengths 6700 to 2300 and three exposures of varying length were made on each specimen. A modification of Lewis's ratio system was employed for quantitative results but no high degree of accuracy is claimed. By using pure silver electrodes the author avoids the errors which result from the impurities always present in carbon electrodes and the accuracy of much of the published work in which carbon electrodes were used is questioned. Various difficulties in this and other methods are discussed, but not always conclusively. The sensitivity and reliability of the method for various elements are discussed but they are not compared sufficiently with those given by other methods of analysis; the arc, for instance, is not as sensitive or as accurate quantitatively for the alkalis as the oxy-coal gas or oxy-hydrogen flames.

The specimens analysed include principally the tissues of marine invertebrates and, in addition, three species of algae, a fish, and a terrestrial invertebrate, *Helix*. Marine invertebrates were chosen because their chemistry is a very varied and comparatively unexploited field and it was considered desirable to confirm and extend the results previously recorded, in particular, by F o x and R a m a g e.

The results obtained from the analyses of sea water and of twenty-four organisms are tabulated and the figures are discussed in relation to the relative degrees of concentration in the organism and its environment. The method of stating the results, namely, "as percentages of the total weight of cations in the ash" is unusual and unfortunate because it is impossible to correlate them with any degree of accuracy with the results of other workers.

Summarizing the results it would appear that no evidence was obtained of any significant accumulation of lithium, boron, strontium, aluminium or silver from the environment (F o x and R a m a g e found marked concentrations of lithium and silver); that barium and lead have a spasmodic distribution; manganese was found in almost all cases but nowhere very

abundantly; iron and copper were generally present; zinc is present in large quantities in some species and cadmium was frequently detected; tin is abundant in *Aeolidia* and two Echinoderms and the presence of fluorine in the mantle of *Archidoris* was confirmed. The paper ends with an extensive list of references which many workers should find invaluable.

The vital part played by minute quantities of cobalt in the life of sheep in Australia and New Zealand is a very striking fact and is evidence of the need there is for the further study of trace elements. In such investigations spectrographic methods will be found indispensable but no one method will suffice for all the elements, even qualitatively. The best quantitative results appear to be given by flame methods for about one-quarter of the chemical elements; beyond these arc spectra should be employed and, in some instances, spark spectra give useful results. Use should also be made of "Spot tests", etc. Further, the method of extracting large quantities of tissues with dilute hydrochloric acid (Nature, 138, 762, 1936) possesses distinct advantages and possibilities, as all the trace metals in both animal and plant tissues except part of the calcium, copper, and iron appear to go into solution leaving the greater part of the organic tissue behind.

H. R.

C. F. Humphries and W. E. Frost. "River Liffey Survey. The Chironomid Fauna of the Submerged Mosses." Proc. Roy. Irish Acad. Vol. XLIII, Sec. B, No. 11, pp. 161—181, 13 figs. Dublin, 1937.

The larvae of Chironomids are frequently the most abundant animals in a river, living either on the bed or amongst submerged vegetation. They are an important source of food, particularly for young salmon and trout and doubtless other fishes, and various members of the family are valuable indicators of pollution but their study is greatly handicapped by the difficulty of identifying them. This paper, based on material collected by Miss Frost and the late Mr. R. Southern in the course of a survey of the Liffey, is therefore of very great interest.

It is a painful commentary on our deplorable ignorance of the commonest animals of our rivers, that, of the larvae examined, Miss Humphries (who is a specialist on this group) found 91·2 per cent. to be unnamable as they were immature Orthocladiariae. All the pupae and the remaining 8·8 per cent. of the larvae were identified as far as the genus though in very few cases was the species determined.

The material was collected from two very different places, from Straffan where the Liffey is an alkaline stream flowing through agricultural land only 180 feet above sea level, and from Ballysmuttan, where the water is acid and the river flows through hill pastures and moorland, and although the animals were all living among moss the differences in chemical environment were considerable. Yet, so far as could be determined, the composition of the Chironomid fauna was very similar in both. This finding is most interesting but we should like to know whether the similarity extends to species.

The study of river ecology will make little further progress until it is possible to identify at least the commoner insect larvae to their species at all stages and it is to be hoped that Miss Humphries will find time and opportunity to extend her work on Chironomid larvae. Several new types are described in this paper and there can be no doubt that systematists would find fluviatile material interesting.

The only criticism of this work is that whilst it may be impossible to give a key for the generic identification of Chironomid larvae, for which the reviewer hoped, it would have been helpful to include in the literature list all the important sources of information on the subject.

F. T. K. P.

R. Spärck. "Ringkøbing Fjords Naturhistorie i Brakvandsperioden 1915—1931." pp. 252. Andr. Fr. Høst & Søn, København, 1933—1936.

Der stattliche, unter Mitwirkung verschiedener dänischer Gelehrten von dem leider zu früh verstorbenen A. C. Johansen und H. Blegvad herausgegebene und von R. Spärck redigierte Bericht über die in den Jahren 1921—1931 angestellten biologischen Untersuchungen im abermals brackischen Ringkøbingfjord liegt nunmehr vollständig vor. Ich habe seinerzeit[1]) schon kurz die in den letzten zwei vom Redaktör verfassten und als Separat-Abzüge erschienenen Kapiteln mitgeteilte Zusammenfassung referiert und möchte in Bezug auf die Veränderungen, die sich im Laufe der Zeit in diesem interessanten Gebiet vollzogen haben, zunächst auf jenes Referat hinweisen.

In einer kurzen, von Blegvad und Spärck verfassten Einleitung werden Johansen's Verdienste um die Erforschung des Fjords gebührend gewürdigt. Sein Bild steht dem Titel des Werkes gegenüber.

Die erste Abhandlung ist von J. P. Jacobsen und enthält eine mit vielen Tabellen und Kurven ausgestattete Beschreibung der Temperatur- und Salzgehaltverhältnisse im Untersuchungsgebiet. Wie zu erwarten war, zeigte der durchschnittliche Oberflächensalzgehalt von Jahr zu Jahr nicht unerhebliche Schwankungen. Aus der Tabelle 3 (S. 5) geht hervor, dass er im Jahre 1921 extrem hoch, 8·62 $^0/_{00}$, im Jahre 1927 dagegen extrem niedrig, 2·98 $^0/_{00}$ war. Diese Zahlen beziehen sich auf Beobachtungen an der etwa in der Mitte des Fjords gelegenen Station B_1; der mittlere Salzgehalt war hier am Boden, in einer Tiefe von 5·0—6·5 m., bedeutend höher als an der Oberfläche, 9·38 $^0/_{00}$ bezw. 5·96 $^0/_{00}$. Die Oberflächentemperatur folgt im allgemeinen derjenigen der Luft; eine Verzögerung des jährlichen Temperaturwechsels am Boden, im Vergleich mit dem des Bodenwassers im Kattegat und des Grossen Beltes, war nicht nachweisbar.

Der botanische Abschnitt enthält zwei Beiträge. Der erste, von J. Iversen, bringt die ersten Ergebnisse einer sehr eingehenden Untersuchung der Vegetation des Fjords mit ausführlichen Daten über die Verbreitung der höheren Pflanzen und der Characeen, sowie einige Angaben über die beobachteten Algen, (Rhodophyceen, Phaeophyceen, Chlorophyceen). Im Anschluss an Kolbe's Halobiensystem unterscheidet er: (1) Euhalobien, das sind marine Pflanzen, in schwach-brackischem Wasser (NaCl<8 $^0/_{00}$) fehlend. Beispiel: *Zostera marina* und *Z. nana*. (2) Mesohalobien, spezifische Brackwasserpflanzen ($\pm$ 2—20$^0/_{00}$ NaCl): *Scirpus parvulus*, *Zanichellia*-Arten und drei Characeen, *Ch. baltica*, *Ch. crinita* und *Tolypella nidifica*. (3) Oligohalobien, Süsswasserpflanzen, die eine geringe Versalzung (bis zu 8 $^0/_{00}$) ertragen.

Das Phytoplankton wurde von E. Steemann Nielsen bearbeitet. Der grösste Teil des Fjords enthielt, wie zu erwarten war, ein typisches Brackwasserplankton, wie gewöhnlich aus zwei Komponenten bestehend: (1) spezifische (mesohaline) Brackwasserarten und (2) Süsswasserarten, die zwar

[1]) Journ. du Conseil, XII, 1, 1937, p. 103.

vielfach aus dem Binnenlande beschrieben sind, jedoch im schwachbrackischen Wasser überall besser gedeihen. Nur in der Umgebung des engen Abflusses in die Nordsee, Nyminde Gab, wurde rein marines Plankton gefunden. Im Frühling bildete *Dictyosphaerium pulchellum* die Hauptmasse des Fjordplanktons, im Hochsommer *Nodularia spumigena.* Das sehr ausführliche Fangverzeichnis enthält nicht weniger als 87 Arten, darunter eine neue Ulothrichacee, *Binuclearia submarina* nov. spec., die S. 43 beschrieben und abgebildet wird. Auffallend ist das Fehlen von *Thalassiosira baltica.*

Die nächste Abhandlung bezieht sich auf das Zooplankton und wurde von P. Jespersen geschrieben. Das Fangverzeichnis enthält 36 Arten. Auch unter den tierischen Komponenten wurden die euhalinen nur im Nymindestrom und dessen unmittelbarer Umgebung beobachtet. Die Figur 2, S. 56, enthält wichtige Daten über das Vordringen dieser Tiere in das weniger salzreiche Wasser. Im Fjord selbst bildeten Rotatoren, namentlich *Synchaeta*-Arten, *Keratella* (= *Anuraea) cruciformis* und *Filinia* (= *Triarthra) longiseta* sowie Copepoden, besonders *Eurytemora hirundoides* und *Acartia* (*Acanthacartia*) *tonsa* den Hauptbestand des Zooplanktons. Die letztgenannte Art war bereits im Juli 1921 massenhaft vorhanden; beide fanden optimale Bedingungen im Mesohalinikum, während ihre Zahl im Nymindestrom nach der Mündung zu allmählich geringer wurde.

P. L. Kramp hat die Echinodermen, Bryozoen, Hydroiden und Vorticelliden bearbeitet. Die beobachteten Arten lebten fast ausschliesslich im Nymindestrom und zwar besonders in seinem salzreicheren südlichen Teil. Der sehr euryhaline marine Hydroide *Laomedea gelatinosa* drang bis in den nördlichsten Teil des Stromes vor, bis querab Rödsand Hage, und genau hier lag auch die äussere Grenze für die beiden, namentlich im Küstengebiet des eigentlichen Fjords weitverbreiteten Brackwasserarten: *Cordylophora lacustris* (= *C. caspia*) und *Membranipora crustulenta.*

Aus dem nun folgenden Beitrag, Würmer, von Hj. Ditlevsen sei hervorgehoben, dass von den Polychaeten nur *Nereis diversicolor* und *Notomastus latericius* die nach Schluss des Hvide Sand Kanals erfolgte Erniedrigung des Salzgehalts im Fjord ertragen haben; die übrigen, von denen *Scoloplos armiger* weitaus der häufigste war, sind verschwunden. Dagegen hat sich eine früher nicht beobachtete Art eingefunden und zwar *Alkmaria romijni,* eine kleine Ampharetide, die in neuester Zeit in verschiedenen nordwest-europäischen Brackwassergebieten entdeckt wurde und als eine richtige "Leitform" des Mesohalinikums zu betrachten ist.

Erik M. Poulsen bearbeitete die Malakostraken und Cirripedien von welchen in den Jahren 1919—1931 nicht weniger als 19 bezw. 2 Arten zur Beobachtung gelangten, davon allerdings die meisten nur in der polyhalinen Zone. Der Autor unterscheidet sehr richtig drei Kategorien (diese Einteilung gilt übrigens auch für die meisten anderen Tiergruppen), nämlich: (1) Süsswassertiere, die ihre Hauptverbreitung, im Süsswasser haben und von hier mehr oder weniger tief in das Brackwasser vordringen können; (2) Brackwassertiere, das sind Tiere, die ihre Hauptverbreitung im (mesohalinen) Brackwasser haben und deren Verbreitungsgrenze auf der einen Seite vom Süsswasser, auf der anderen vom Meerwasser gebildet wird und schliesslich (3) marine Arten, die ihre Hauptverbreitung im Meere haben und im Brackwasser bisweilen bis zur Süsswassergrenze durchdringen können. Von der ersten Kategorie wurde nur *Asellus aquaticus* im inneren Teil des Fjords beobachtet. Als spezifische Brackwasserarten nennt der Verfasser: *Palaemonetes varians, Mysis vulgaris* (= *Neomysis integer*), *Iaera marina* (= *I. albifrons*), *Gammarus duebeni* und *G. zaddachi.* Zu den Salzwasserarten werden auch *Corophium volutator* und

Balanus improvisus gestellt; beide sind jedoch meiner Ansicht nach besser zu den genuinen Brackwasserarten zu rechnen, da sie ihre Hauptverbreitung im Mesohalinikum haben.

Die Insektenfauna, mit Ausschluss der Dipteren, über die R. Spärck berichtet, wurde von Kaj L. Henriksen bearbeitet. Der Verfasser gibt S. 116 eine interessante Tabelle, aus der hervorgeht, bis zu welchem maximalen Salzgehalt die verschiedenen Arten gefunden sind. Unter den Dipteren spielen begreiflicherweise die Tendipediden die Hauptrolle. Die typisch mesohalinophilen Larven von *Chironomus plumosus* var. *semireductus* bildeten an einigen Stellen des Fjords die Hauptmasse des tierischen Bestandes.

Der zuletzt genannte Autor hat auch die Mollusken bearbeitet. Im ganzen wurden 14 Arten beobachtet. Zehn fanden sich nur im Nymindestrom, darunter *Macoma baltica, Mya arenaria* und *Hydrobia ulvae,* die zu Anfang der Brackwasserperiode jedoch auch im eigentlichen Fjord überall vorkamen. *Scrobicularia piperita* verschwand gänzlich gegen Ende dieser Periode. Die Verbreitung der beiden Süsswasserarten, *Bithynia tentaculata* und *Lymnaea pereger* war auf die unmittelbare Nähe der Flussmündungen beschränkt. Als spezifische Brackwasserform kam einzig und allein *Hydrobia jenkinsi* in Betracht, die im Gegensatz zur früheren Brackwasserperiode (1845—1910) in grossen Mengen vorhanden war. Bemerkenswert ist, dass eine andere mesohalinophile Art, *Congeria* (= *Dreissensia*) *cochleata,* die neuerdings auch in Norddeutschland gefunden ist, offenbar noch nicht in den Ringkøbingfjord vorgedrungen war. Auch das gänzliche Fehlen der Opistobranchier, unter denen es mehrere gibt, die auch im Brackwasser gut gedeihen, ist auffallend.

Über die Fische liegt ein sich hauptsächlich auf die Fangstatistik stützender, mit Tabellen und Kurven erläuterter Bericht von H. Blegvad vor. Alles in allem war der Ertrag der Fischerei im Fjord während der letzten Brackwasserperiode bedeutend geringer als in den vorhergehenden Jahren 1910—1915. Der Fang der wichtigsten Plattfische, Scholle und Flunder, hat seit etwa 1912 sehr nachgelassen; die erstere ist in der Brackwasserperiode sogar gänzlich verschwunden. Der Verfasser vermutet übrigens, dass dieses Verschwinden nicht unmittelbar durch die Verringerung des Salzgehalts, sondern durch das Fehlen geeigneter Nahrung verursacht wurde. Die Flunder blieb während der Brackwasserperiode kleiner als vorher, hatte aber, wie behauptet wurde, einen besseren Geschmack und war auch mehr geeignet zum Räuchern. Auch die übrigen Seefische sind seit dem Schluss des Hvide Sand Kanal allmählich verschwunden. Der Aal hat sich selbstverständlich auch im Brackwasser behaupten können und bildete nach wie vor den wichtigsten Gegenstand der Fischerei im Fjord. Wie bei der Flunder konnte auch beim Aal die Beobachtung gemacht werden, dass die in den Brackwasserperioden gefangenen durchschnittlich kleiner waren als die im salzigen Wasser gefangenen. Der Hering war immer reichlich vorhanden und laichte, wie der Sprott, im Fjord. Der Fang von Lachs und Seeforelle zeigt bedeutende Schwankungen und ist in den letzten Jahren stark zurückgegangen. Von den übrigen Süss- resp. Brackwasserfischen ist namentlich die grosse Maräne von Bedeutung, obschon die Fänge im Vergleich zu denen der Salzwasserperiode relativ gering waren. Dasselbe gilt vom Stint. Alles in allem war die letzte Brackwasserperiode weniger ergiebig als die vorhergehende, und die Süss- und Brackwasserfische bildeten nur einen armseligen Ersatz für die wertvolleren Seefische.

Auch die Vögel des Ringkøbing Fjord sind in diese Monographie mit aufgenommen. Å. Vedel Tåning hat darüber eine sehr ausführliche, 70 Seiten umfassende und mit vielen schönen Abbildungen geschmückte

Abhandlung geschrieben. Doch kann hierauf nicht weiter eingegangen werden.

Die beiden nun folgenden Arbeiten beziehen sich auf die Bodenfauna als Ganzes sowohl in qualitativer wie in quantitativer Hinsicht. H. Blegvad berichtet zunächst über seine Befunde am Schluss der Salzwasserperiode. Er konnte feststellen, dass *Macoma baltica* damals das überall prädominierende Tier war und der Fjord somit zur *Macoma*-Gemeinschaft gehörte. In der zweiten Abhandlung, über die ich *l. c.* schon ausführlicher berichtet habe, zeigt der Redaktör, wie sich die marine Fazies der Bodenfauna allmählich in eine vorwiegend mesohaline verwandelte bis schliesslich eine Tendipediden- (Chironomiden-) Gemeinschaft mit deren typischen Begleitern entstand.

Den Schluss des Bandes bildet eine ebenfalls von R. Spärck verfasste Abhandlung über die Fauna des Fjords im Vergleich zu anderen nördlichen Brackwassergebieten. Auch hierüber habe ich schon früher (*l. c.*) referiert.

Sämtliche Beiträge sind mit einem englischen Résumé versehen. Das Buch ist — wie die wissenschaftlichen Publikationen der dänischen Forscher überhaupt — vorzüglich ausgeführt und bildet, so wie es vorliegt, einen wertvollen Gedächtnisband für den ausgezeichneten Hydrobiologen und lieben Freund Dr. A. C. Johansen.

H. C. R.

J. H. Orton. "Oyster Biology and Oyster Culture." pp. 211, 57 figs. (5/-) Edward Arnold & Co, London, 1937.

This book includes the substance of two lectures on "Recent researches on the Natural History of the Oyster" and on "Modern problems relating to oyster-culture." In the first part the chapters on shell, structure, anatomy, and mode of life are followed by a detailed description of the shell movements. The water currents inside the shell and the mechanism of feeding are dealt with very extensively. Many data are given on such subjects as fattening, shell growth, deposition of shell material, etc. This lecture is concluded by a description of spawning and sex change.

In the second part the author discusses the period of incubation of the young, the lifetime of free-swimming larvae, methods of spat-collection, the growth of the different stages, and artificial production in tanks. An extensive description is given of enemies, unfavourable environmental conditions and mortality. The book is concluded by a chapter on pollution and purification. Many references in the text make it easy to find the literature on each subject.

In general a very good review of English and American literature is given; the rest, however, is somewhat neglected, e.g., the investigations done in Heligoland. The French literature is only represented by one title. In particular, nothing is said of the French method of predicting the most propitious time for the laying of cultch. Orton puts forward his own method of predicting this time by a weekly examination of samples of oysters and determining the percentage of oysters with larvae. The French method, however, of counting the different stages of development of the larvae in the plankton seems to be much better. That the oyster larvae seem to prefer to settle on a "dark and smooth perhaps rather than rough" surface is not yet proved. On the contrary, in *Ostréiculture*, 1937, No. 7, Thiéblemont records 3½ times as many spat on white as on black tiles. Also an opinion exists that the surface must not be too smooth, like glass, for instance.

That the disease among the Dutch oysters consisting of black spots inside the shell should be "excretory deposits" seems to be a somewhat premature judgement. In the chapter on "Pollution and purification" nothing is said of the severe hygienic control of the oysters in France and Holland, for example. In general, the book gives very good information on many subjects, and everyone interested in oysters should read it. It is well printed, and richly illustrated.

B. H.

Current Bibliography.

Prepared by the Editor with the assistance of Miss Thursby-Pelham.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

Subscribers and those on the distribution list will receive regularly upon application to the Administrative Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

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